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KPTC 5000... Dr. Oltjen-FYI

United States
Department of
Agriculture

Agricultural
Research
Service

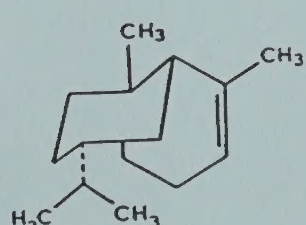
Report

ARS-WIDE WORKING CONFERENCE

INSECT SEMIOCHEMICALS:
OPPORTUNITIES AND CONSTRAINTS FOR DEVELOPMENT AND USE

Atlanta, GA

May 7-10, 1990



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Staff

Preface

ARS is justifiably proud of its extensive program in semiochemical research. The myriad projects comprising the program are conducted at some 30 ARS facilities and involve approximately 150 scientists from a variety of disciplines. Semiochemicals constitute a particularly fruitful field for research: they play a dominant role in the most vital aspects of insect behavior; they govern the activity of insects--both pests and beneficials--in seeking food, mates, oviposition sites, and the protected places where they pass the inactive stages of their development. ARS scientists have searched for and identified more selective insect control methods that exert their effects only on the target species. Semiochemicals are often quite specific and can provide such selective weapons.

During the conference it became clear that development and wider utilization of semiochemicals are impeded by certain overriding issues. Some of these issues include, but are not limited to, fiscal resources, formulation and application technology, large-scale field trial design and evaluation, patent questions, regulatory considerations, and farmer/industry/consumer acceptance. Increased chemical, engineering, and integrated biological research can help fill some of these gaps; producer and consumer education can help fill others.

From the viewpoint of the ARS National Program Staff (NPS), a key function is to ensure that ARS research projects singularly and collectively form an effective response to specific national problems, and thus conform to the Agency's program plan. To do so, the NPS utilizes program planning conferences and workshops to help with proper development of projects and programs and to ensure that the projects are indeed focused on specific national needs. From the information generated by conferences, workshops, and other sources, the NPS can develop and prioritize a listing of problems, research objectives, and resource needs for use in systematic program planning and guidance of ARS research programs aimed at addressing national issues.

As stated during my opening remarks at the conference, one very important product of the workshop would be the document that follows this preface. This document addresses specific research needs for semiochemicals. The information will provide an important foundation for program strengthening and expansion, coordination, decisionmaking on resource allocation, and implementation actions for NPS. Finally, this information will provide a foundation for ARS strategic and program implementation planning.

The National Program Staff expresses its gratitude and appreciation to all conference attendees for their participation. The conference was extremely productive; it was upbeat, and it met its projected objectives. Special appreciation is accorded to Drs. Peter Price, Ring Carde, Madeline Mellinger, Hank Cutler, Lynn Davis, Richard Parry, Robert Burns, and Ernest Corley for their very special contributions to the conference and for their support and interest. The NPS would also like to extend a very special thanks to the steering committee members: Drs. R. Ridgway, R. Heath, J. Lewis, W. Snow, R. Flath, and R. Patterson. Appreciation is extended to Dr. May Inscoe of the Insect Chemical Ecology Laboratory, Beltsville, MD, for all of the generous time and effort she donated during the preparations of the workshop. The NPS is also very grateful to those who were assigned to serve as moderators, reporters, and lead discussants in the various sessions and for the excellent manner in which the sessions were handled. The NPS is deeply indebted to the industrial representatives and the representatives from EPA, the Forest Service, and APHIS for their valuable contributions, and to the registration and local arrangements committee, especially Dr. Wendell Snow, Rose Mayhew, and Dixie Hyde. Again, thanks much to all participants for having made this working conference such a success.

Robert M. Faust
National Program Leader
Crop Protection

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I. EXECUTIVE SUMMARY

A major goal of the Agricultural Research Service (ARS) is the discovery of new principles and development of safer methods for controlling insects and other pests that infest agricultural commodities. Insects are developing resistance to many of the current control methods that rely upon chemical pesticides, and the safety of these chemicals is increasingly being questioned. Research aimed at developing environmentally compatible pest management systems is a high priority for ARS; insect semiochemicals have enjoyed increasing attention as feasible and environmentally safer tools for this purpose. More than 100 ARS scientists are now involved in various aspects of insect semiochemical research at some 30 locations.

An ARS-wide working conference devoted to insect semiochemicals was held on May 7-10, 1990, in Atlanta, GA. The purpose of the conference was to: (1) foster improved communication and linkage among ARS scientists and others having an interest in semiochemicals; (2) review the state-of-the-art of semiochemical research and programs and address constraints that pose barriers to wider use of semiochemicals; (3) determine research needs and opportunities; and (4) identify major areas of emphasis for future ARS research and technology transfer. Participants included representatives from the ARS National Program Staff, management, and numerous ARS research units, as well as private industry, universities, and other Federal agencies.

Significant ARS accomplishments highlighted during the workshop included:

(1) Discovery and identification of numerous insect pheromones from pests of cotton, corn, soybean, vegetables, fruit, citrus, and stored products; the fire ant queen pheromone; and the nasanov pheromone for trapping Africanized bee swarms.

(2) Development of attractants for Mediterranean fruit fly and other tephritid fruit flies, gypsy moth, pink bollworm, screwworm, boll weevil, corn earworm, black cutworm, fall armyworm, corn earworm, stored product insects, and others.

(3) Discovery and identification of insect ovipositional stimulants and deterrents, growth inhibition/feeding deterrents, and repellents for mosquitoes and biting flies.

(4) Discovery that beneficial insects exploit pheromones and other semiochemicals for host location and that "learned" behavior can influence responses to semiochemicals.

(5) Development of mating disruption systems for codling moth, peachtree and lesser peachtree borers, tomato pinworm, and--in cooperation with APHIS--oriental fruit moth and pink bollworm; development of insect suppression systems for screwworm, gypsy moth, oriental fruit fly, melon fly, and Indian meal moth; and development of lures for other lepidoteran pests and insects that affect man and animals.

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(6) Development of delivery systems and commercial dispensers for synthetic attractants, especially for the medfly and bollweevil; design and validation of new insect trap designs and monitoring systems for boll weevil, Japanese beetle, Southwestern corn borer, peach tree borer, corn rootworm, tephritid fruit flies, sunflower moth, and stored product insects; and development of population models for the cotton bollworm and a predictive model for ticks.

Many high-priority future research needs and opportunities for now and the future were identified, including:

(1) Further pioneering research on insect biology, biochemistry, physiology and ecology, and the molecular biology of sex pheromone regulation and reception.

(2) Continued research on discovery and identification of new pheromones, attractants, adjuvants, ovipositional and feeding stimulants or deterrents, and repellents--especially for Homoptera, Heteroptera, Hymenoptera, Coleoptera, and for insects affecting man and animals.

(3) Improved understanding of the synergism of pheromones and host-plant volatiles, parasite/predator host location behavior, the role of host-plant odors for tephritid fruit flies, the potential role of semiochemicals in augmentation, and the relationship of semiochemical structure to its activity.

(4) Further research on lures, dispensers and formulations, pheromone ratios/release rates and performance criteria, the role of semiochemicals in insect dispersion/migration behavior, population modeling/mass trapping, and the effects of semiochemical technology on non-target organisms.

At the technology transfer and regulatory sessions, conference participants agreed that close cooperation between the private and public sectors is essential for semiochemicals to have a major impact. Emphasis was also placed upon the importance of mutual involvement early in the research and the continued availability of the expertise and experience of the ARS inventor after a patent is licensed and the technology moves into development. Also, the EPA will be examining the regulatory process--i.e., general internal procedures, the use of generic EUP's, and opportunities for additional exemptions from certain data requirements--to determine where improvements can be made.

II. ARS Mission & Needs for Environmentally Compatible Insect Management

The Agricultural Research Service (ARS) is the Department's principal intramural research agency. It has long-standing working relationships with the other research agencies in the Department, the State Agricultural Experiment Stations, and the private research sector. The ARS also works closely with the action agencies in the Department and serves as the research arm for many of them. Interagency programs within the Department are critical in such areas as soil and water conservation, range improvement, control of plant and animal diseases, and food safety.

The mission of the ARS is--

> To plan, develop, and implement research that is designed to produce the new knowledge and technologies required to assure the continuing vitality of the Nation's food and agricultural enterprise. As a Federal research agency, ARS (1) addresses problems that are of legitimate national concern, (2) conducts research that is appropriate for the Federal Government, and (3) exploits the unique capabilities of ARS scientists and the facilities they operate - a combination that forms an integrated and coordinated national resource that is not duplicated by others in the full U.S. agricultural research and development system.

During the past few decades the consumer public has insisted on development of safer pest control methods to supplement and offset extensive reliance on synthetic organic chemical pesticides. Progress has been made in such areas as host plant resistance, expanded use of predators, parasites and pathogens, semiochemicals (pheromones, plant attractants, repellents, etc.), insect sterility, biotechnology, cultural control and overall insect pest management. Although good progress has been made at developing biologically-based methods of pest control, synthetic chemical pesticides are still our major means of protecting our food and fiber crops from pests. New, environmentally compatible pest control technologies are slowly replacing synthetic pesticides. This will be an even more critical issue as more registered pesticides are banned. Increased research focus on semiochemicals, in addition to natural plant products, insect hormones, autocidal methods and genetic engineering is needed, and is viewed as one of the high priority areas of research for ARS.

III. Objectives & Charge to the Conference

The overall charge of the working conference was to assess needs and opportunities for research in insect semiochemicals as they relate to their potential use as environmentally compatible tools for pest management. The working conference was specifically designed to provide a forum for expressing views and ideas for the future.

Specific objectives were to:

1. Foster improved communication and linkage among ARS scientists and others having an interest in semiochemicals;

2. Determine the current status and constraints in the utilization of insect semiochemicals as components of pest management tools;

3. Determine research and identify needs and opportunities for exploiting insect semiochemicals;

4. Identify major areas of emphasis for future research and technology transfer.

IV. Conference Reports

REPORT A. OPENING PLENARY SESSION (SUMMARIES) REPORTERS: H.Oberlander
J. L. Krysan

Needs for Alternative Methods of Insect Control - M. Mellinger:

The best tools now available for management of insect pests are not good enough for such insects as leafminers, diamondback moth, sweet potato whitefly, fall armyworm and pepper weevils because of a rapid development of pesticide resistance as well as the induction of secondary pests subsequent to intense use of pesticides. There should be close interactions between scientists, growers and consultants to reverse the present trends and develop alternative pest control strategies. The importance of environmental issues was emphasized, as was the need for area wide control as envisioned by Dr. E. F. Knipling.

Signaling and Espionage with Semiochemicals - R. Carde:

Some of the highlights in semiochemical research over the past 5 years was reviewed. In addition an overview of the various processes that need to be examined in the laboratory as well as under field conditions to better understand the way in which semiochemicals are perceived and lead to behavioral effects was presented. In the area of pheromone production he emphasized the importance of research on endogenous rhythmicity, environmental cues, regulation by PBAN and the terminal abdominal ganglion in moths, biosynthetic pathways, and the amount and ratio of pheromone components that are actually released. The complex nature of the male response was also discussed, including the role of antennal sieving, signal transduction, neural processing and flight maneuvers. New neurophysiological research was discussed which related the effects of semiochemicals on sensory input to the insect, central nervous system processing of the signals, and the initiation of appropriate behavioral responses.

Plant Chemistry - H. Cutler:

Many biologically-active natural products occur that may be useful as ecologically safe agrochemicals. Some of these chemicals control insect behavior and others have a narrow spectrum of pesticidal effects. Reciprocal intraspecific effects occur, i.e., plants and fungi produce compounds that affect insects, and insects produce compounds that affect microbes or plants. Molecules with the same basic structure, but bearing slight modifications, occur across the plant, microbe and insect worlds, suggesting evolutionary conservatism of these chemicals. Several plant-derived chemicals were described including DIMBOA, which is an antifeedant in corn and brassinolides, which affects both plant growth and inhibits insect molting. Another set of compounds are produced by termites and affects plants. ARS was encouraged to exploit such compounds as patentable products through interactive research among plant scientists and entomologists.

Population Ecology - P. Price:

A broad perspective was presented concerning a community and population view of plant-insect-natural enemy interactions over a landscape. Communities of

Needs for Alternative Methods of Insect Control - M. Wellinger:

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parasitoids vary locally and geographically , which makes it probable that various parasitoid biotypes occur, and that it will be necessary to take this into account as parasitoids are selected for biological control programs. As landscapes, agricultural systems are almost the reverse of primaeval nature, plants form small patches of early succession are now grown in large monocultures. From this analysis the following was concluded: (1) Parasitoids that are adapted to early succession will generally disperse widely among small patches; for agriculture, wide dispersers may be maladaptive and hard to manipulate with semiochemicals; (2) Parasitoids adapted to late succession may be less dispersive and easier to manipulate with semiochemicals, but hosts may be more resistant to the parasitoids; (3) Biotypes of parasitoids should be sought that match the environment where semiochemicals will be used, especially in terms of dispersal; and (4) Different parasitoids will probably be moe effective at different stages in a host outbreak, depending on whether they are good colonists and weak competitors, or vice versa.

REPORT: B. SCIENCE WORKSHOP — REPORTERS: H. Oberlander, J. Menn
1. Bioregulation

Introduction:

Although the chemistry and behavioral effects of sex pheromones are understood for many pest insect species, the endogenous regulation of the initiation and termination of pheromone biosynthesis are now being intensely investigated. Potentially, neurohormonal regulation of pheromone biosynthesis could be manipulated for insect control. However, this can only be accomplished through continued pioneering research by ARS on the biochemistry, physiology and molecular biology of neuropeptides and other regulatory molecules that control the production and release of sex pheromones.

Selected ARS Accomplishments:

1. Isolation and identification of Pheromone Biosynthesis Activating Neuropeptide (PBAN) from *Heliothis* spp. - Beltsville

2. Isolation of Receptivity Terminating Factor (RTF) from *Heliothis* spp. - Beltsville

3. Isolation of Pheromone Biosynthesis Suppression Factor (PBSF) from *Heliothis* spp. - Gainesville

4. Determination of the terminal step in pheromone biosynthesis in *Heliothis* spp. - Gainesville

5. Demonstrated the role of host-plant volatiles in pheromone production in several *Heliothis* spp. - Beltsville

Current Research:

ARS is very active in research on bioregulation of pheromone production, particularly with *Heliothis* spp. The laboratories with major resources devoted to this area are located at Beltsville and Gainesville.

1. Pheromone Biosynthesis Activating Neuropeptide (PBAN) in *Heliothis* spp:

   a. External cues including plant derived compounds, photoperiod and temperature are being fully explored - Beltsville

   b. Neuro-regulation of pheromone biosynthesis is being investigated with respect to the mode of transport of PBAN, role of the terminal abdominal ganglion, and identification of receptors and potential role of biogenic amines - Beltsville and Gainesville.

   c. Analogs of PBAN are being synthesized for structure-activity studies - Beltsville

2. Isolation and identification of Pheromone Biosynthesis Suppression Factor which is produce by the bursa copulatrix in *H. zea* - Gainesville

3. Genetics of pheromone production by Heliothis spp. and hybrid and backcross insects are being studied - Gainesville

4. The biochemical mechanisms of biosynthesis of conjugated dienal and trienal sex pheromones of Manduca sexta are being investigated - Gainesville

5. A substance (RTF) from the male tubular accessory glands that suppresses pheromone production after mating is under investigated - Beltsville

Research Needs and Opportunities:

ARS has pioneered key research areas in neuroregulation of pheromone biosynthesis and release. To capitalize on these landmark research discoveries additional resources and effort should be directed to the following objectives:

1. Pheromone Biosynthesis Activating Neuropeptide (PBAN):

   a. Identify neurohormones processed to PBAN.

   b. Characterize processing and degrading enzymes involved in PBAN synthesis and catabolism.

   c. Isolate and clone genes that regulate PBAN in economically important lepidopteran species.

   d. Conduct research on inhibitors that interfere with PBAN synthesis, transport and function.

2. Pheromone Biosynthesis Suppression Factor (PBSF) and Receptivity Terminating Factor (RTF).

   a. Complete identification of PBSF and RTF.

   b. Determine mode of action of PBSF and RTF on inhibition of pheromone production.

3. Investigate environmental cues that impact on bioregulation of pheromone synthesis and release.

4. Extend findings on bioregulation of pheromone production in Heliothis spp. to other lepidopteran species, and other orders of insects.

5. Evaluate novel methods of pest control based on utilizing PBAN, RTF or PBSF, mimics or inhibitors of these agents; and explore possibilities of inserting neuropeptide genes into baculoviruses to disrupt key physiological events in target insects.

REPORT: B. SCIENCE WORKSHOP
2. Perception

REPORTERS: H. Oberlander
J. Menn

Introduction:

Insects live in a world of chemical stimuli that regulate their dispersal, feeding and mating. Perception of these stimuli involves both peripheral and central processing. The sensitivity and specificity of the receptors determine what cues the insect detects in the environment. The central nervous system in turn directs appropriate behavioral responses. A greater understanding of these neuronal processes is important for successfully exploiting control of pest insects with semiochemicals.

Selected ARS Accomplishments:

1. Identification of specialist receptor neurons that detect pheromone components in the Boll Weevil - Mississippi

2. Electrophysiological studies that led to enhancement of the boll weevil pheromone with green leaf volatiles - Mississippi

3. Identification of specialist receptor neurons that detect naturally occurring concentrations of pheromone components in the Cabbage Looper - Gainesville

4. Neurophysiological studies of the antennal sensitivities of the Mediterranean fruit fly and the Oriental fruit fly to known male lures and various volatiles which result in enhancement of the pheromones with green leaf volatiles - Hilo and Albany

5. Neurophysiological studies of the antennal sensitivities of the corn earworm, tobacco hornworm, and the tomato hornworm to known pheromones and various volatiles which result in enhancement of the pheromones with green leaf volatiles - Albany and Beltsville

Current Research:

ARS has several neurophysiological specialists who interact with both applied and basic research programs at several laboratories. Current research activities include the following:

1. Antennal sensitivity and selectivity of fruit flies, boll weevils and other species to kairomones, baits, host plant constituents and sex pheromone components - Albany, Gainesville, Hilo, Mississippi

2. Antennal sensitivity of chalcids to volatiles of the flowers, seed pods, and leaves of their host plants - Albany

3. Sensitivity and selectivity of specialist neurons of the boll weevil and other species to pheromone and host plant odors - Mississippi

4. Sensitivity and selectivity of specialist neurones in the cabbage looper with respect to individual pheromone components at concentrations encountered in nature - Gainesville

5. Correlation of peripheral and central neurophysiological responses with discriminative and other behavioral responses to pheromones, kairomones and host-plant volatiles - Albany, Gainesville, Hilo, Mississippi

Research Needs and Opportunities:

1. Develop and/or improve sensitive, rapid and effective neurophysiological bioassays to evaluate insect semiochemicals.

2. Disruption of semiochemical-mediated behavior requires increased knowledge of the neurophysiological mechanisms of both peripheral reception and central processing of the following:

   a. Pheromonal blends and host plant odors, alone or in combination.
   b. Candidate disruptants.
   c. Neuropeptides and "designer molecules".

3. Neurophysiological responses of field populations of pest insects should be studied to assess variability in response to semiochemicals.

4. Neurophysiological basis of gustation needs to be explored as part of a program to develop insect antifeedants.

REPORT: B. SCIENCE WORKSHOP
3. Chemistry - Insects

REPORTER: O. T. Chortyk
R. Heath

Introduction:

Insect semiochemicals are represented by many classes of compounds, including both volatile and non-volatile hydrocarbons, olefins, alcohols, aldehydes, lactones, amino-acids, and proteins. They function as attractants, alarm and trail pheromones, stimulants, deterrents and recognition chemicals.

Selected ARS Accomplishments:

ARS scientists have identified a large number of pheromones. In addition to determining the chemical composition, the release rate and ratios of the blend of phermonal compounds has been accurately determined in some. Most pheromone research has resulted in field application and many of these have found commercial application through technology transfer. For example, over 10 million boll weevil and 1.5 million Japanese beetle lures are sold annually. With serious problems in insect resistance to commercial pesticides, the use of these semiochemicals assumes paramount importance.

Current Research:

Present chemical analytical techniques and instrumentation are great assets in continuing the identification, and allowing more rapid identifications, of unknown semiochemicals. ARS scientists have pioneered and continue to pioneer "cutting-edge" methods. Chemical synthesis yielding materials for studying the potential of new semiochemicals is continuing. Recent emphasis is on chiral syntheses, which is crucial in some systems. Research is continuing on development of volatile semiochemicals formulations that provide the proper release rates, ratios, longevity, and application methods. Semiochemicals for parasitoids have been discovered and have been shown to be crucial for "learning."

Research Needs and Opportunities:

1. There are still many insect pheromones that need to be identified.

2. There is a need to continue research on developing analytical techniques and sampling methods.

3. There is a need to understand synergism of pheromones and host plant volatiles, i.e., pheromones are not the whole story.

4. There is a need to study chemicals that affect the behavior of beneficial insects and to answer the questions: How do parasitoids locate their larvae hosts: What chemicals are involved in parasitoid oviposition? Can kairomones be used to assist control of plant pests, filth breeding flies, or cockroaches?

5. There is a need for improved bioassays and a need for reliable and specific bioassays for both single and complex mixtures of chemicals.

6. There is a need for research to develop methodology that can determine more accurately the release rates and ratios of semiochemicals.

7. There is a need to develop better analytical techniques for research on non-volatile or water-soluble compounds.

8. There is a need to identify animal-based attractants for biting insects, ie., ticks and blood-sucking flies.

9. There is a need to expand and improve chemical synthesis of pheromone compounds; especially important to produce stereospecific isomers.

10. There is a need to identify ovipositional attractants and feeding stimulants, or anti-feeding compounds, in plants.

11. There is a need to involve industry at the stage of formulation of pheromones (mixtures of lures).

12. There is a need for interdisciplinary approaches to bioassays, ie., the availability of electroantennograms is very limited.

13. The use of semiochemicals for tick control needs to be investigated.

14. Incipient presence of Africanized honey bees in the U.S. indicates a need for research on attractants or repellents to manage these bees.

15. Continued research on use of pheromones to survey or monitor insect population changes is needed.

REPORT: B. SCIENCE WORKSHOP REPORTER: Gueldner/Heath
4. Chemistry - Plants

Introduction:

Plants produce chemicals which affect insect behavior in various ways. These chemicals may be classified as attractants, repellents, feeding stimulants and deterrents, ovipositional stimulants and repellents, and as adjuvants to pheromones. Further knowledge of plant/host interactions should offer significant opportunities for effective insect control using plant semiochemicals.

Selected ARS Accomplishments:

ARS scientists have developed tobacco which is resistant to the tobacco budworm and aphids, and tobacco that attracts the stilt bug. A critical chemical link in these plant/insect interactions is the presence of duvatriene diols. Other accomplishments include the identification of oviposition stimulants and deterrents in tobacco, identification of maysin and chlorogenic acid as growth inhibitors/feeding deterrents of corn earworm and fall armyworm in corn silks and leaves, and development of cotton resistant to *H. virescens*. ARS has obtained several patents as a result of this research, including the use of azadirachtin from neem tree extracts which is a potential control agent for several insect pest species.

Current Research:

Scientists are currently evaluating plant compounds that act as growth inhibitors, feeding inhibitors, oviposition stimulants and deterrents, attractants and repellents from crop plants and non-host plants. Considerable efforts are being made to develop systems to collect volatile semiochemicals released by plants that are attractive feeding stimulants and which can be used to trap female insects. Green leaf volatiles are being further developed as synergists for use with many known pheromones.

Research Needs and Opportunities:

1. Continued research in the use of plant chemicals and pheromones for trap baits is needed.

2. Disciplinary cooperation to elucidate the basis of plant resistance is needed.

3. Additional research in use of floral lures as insect attractants is needed.

4. A better understanding of plant resistance versus stress is needed.

5. Identification of synomones produced by plants that are being damaged by moth larvae that attract parasitoid wasps to larvae is needed.

6. There is a need to develop structure activity relationships of plant semiochemicals via modeling.

7. Studies on plant semiochemicals as bioregulators and their effects is needed.

REPORT: B. SCIENCE WORKSHOP
5. Behavior

REPORTER: C. E. Rogers

Introduction:

Behavior may be defined as "ways in which organisms adjust to and interact with their environment." These responses usually involve movement and changes in position, both individually and collectively.

Selected ARS Accomplishments:

Basic research by ARS has contributed significantly to a better understanding of behavior in many species of insects.

1. Control programs and/or efficient monitoring systems for the boll weevil, Japanese beetle, southwestern corn borer, peach tree borer, corn rootworm, fruitflies, and the sunflower moth have been developed.

2. Demonstrated that males of the tobacco budworm emit pheromones through their hairpencils that evoke female responses.

3. Demonstrated that there are different strategies for male-female responses to semiochemicals from members of the opposite sex in the cabbage looper.

4. Demonstrated that the honeybee has a series of pheromones that control colony aggregation, alarm, foraging and drone behavior, brood development, and queen mating.

5. Demonstrated that specific nocturnal behavioral components are associated with responses to semiochemicals in the corn earworm, tobacco budworm, and pink bollworm.

6. Demonstrated that learned behavior influences responses to semiochemicals by *Microplitis croceipes*.

Current Research:

1. Delineation of the role of female response to male pheromone in mating behavior of the tobacco budworm.

2. Clarification of the strategies used by female and male of the cabbage looper in semiochemical communication.

3. Delineation of the roles of semiochemicals in honeybee behavior, and how these may be used to control hybridization with the Africanized honeybee, and the role of pheromones in tracheal mite infestation.

4. Elucidation of the genetics of behavioral systems and role in semiochemical communication in *Microplitis croceipes*, and antennal responses to host recognition.

5. Elucidation of the role of plant products/byproducts in insect-plant interactions

6. The identification and use of pheromones for specifically desired responses.

7. Definition of the role of physiological state, phenotypic variability, and learning in *M. croceipes* responses to semiochemicals.

Research Needs and Opportunities:

ARS needs proactive behavioral research with semiochemicals designed to reveal fundamental behavioral processes. The following are areas that would benefit from specifically designed research thrusts.

1. Determination of the effects of semiochemicals on non-target organisms.

2. Delineation of the behavioral components of pheromone communication.

3. Improvement of behavioral bioassays for isolating and identifying semiochemicals.

4. Validation of the activity of synthetic semiochemicals.

5. Elucidation of the synergisms between plant volatiles and pheromones.

6. Development of lines (strains) of insects for specific augmentative purposes.

7. Discovery and development of semiochemicals that evoke female immature and ovipositional behavior.

8. Determination of behavioral responses to animal stimuli as well as to plant stimuli.

9. Evaluation of semiochemical communication in beneficial insect species.

10. Delineation of genetically-controlled behavioral processes from environmentally induced behaviors.

11. Development of knowledge bases for predictive behavioral responses to selected semiochemicals.

12. Delineation of the role of semiochemicals in insect dispersal/migration behaviors.

REPORT: B. SCIENCE WORKSHOP
6. Population Dynamics

REPORTER: J. R. McLaughlin

Introduction:

ARS scientists have participated in the discovery of numerous semiochemicals, primarily feeding attractants and sex pheromones that enable the monitoring of insects. These chemicals are commonly used as baits in traps that are deployed as survey tools to detect emergence cycles and relative changes in population densities, provide early warning and estimates of the movement of pests among cropping systems within a cropping area, and detect and follow the migration of insects from known or suspected inoculum sites into pest-free areas. The use of these traps as predictive tools to forecast population levels or damage in specific crops during the growing season has had limited success. Despite this limitation, information provided by these traps is frequently used in ecological studies, is often used in pest management decisions, and is a prominent feature of all area-wide suppression programs.

Selected ARS Accomplishments:

1. Developed attractants for the Mediterranean fruit fly, gypsy moth, pink bollworm, screwworm, and boll weevil has enabled assessment of occurrence, movement, and relative population levels without which quarrantine and area-wide suppression programs could not function.

2. Developed attractants for honey bee and several moth species enable the study of the genetic composition of field populations, thus, allowing determination of changes in population structure caused by the incursion of Africanized bees or by insecticide resistance.

3. Developed attractants for pests such as corn earworm, black cutworm, fall armyworm, and velvetbean caterpillar which have greatly facilitated research in the area of species migration.

4. Developed population models for pests such as the cotton bollworm utilizing data from attractant-baited traps as a primary input.

Current Research:

1. Utilization of trapping information for use in decision making and in predictive models with emphasis on *Heliothis* spp.

2. Research on attractants for females (largely host-plant materials) and combinations of sex lures and host odors with emphasis on *Heliothis* spp., fruit flies, and rootworms.

3. Research addressing causes and effects of insect migration.

4. Research to identify or redefine pheromonal systems of pests.

5. Research on attractants for insects affecting man and animals.

6. Research to define chemicals mediating host-location in parasitoids.

7. Africanized bee incursion and insecticide resistance monitoring.

Research Needs and Opportunities:

1. Efficacy of semiochemicals in description and quantification of pest population dynamics requires greater knowledge of (a) climatic factors, (b) plant diversity and crop phenology, (c) dispersal and migration, (d) natural enemies, (e) species competition, (f) attractant efficiency, (g) trap efficiency, and (h) lures for both sexes of insects, for immatures, and for natural enemies.

2. Lures for crop pests other than Lepidoptera, for soil-inhabiting pests, and for parasitiods, predators, livestock ticks, and cockroaches.

3. Development of various lures with different behavioral modalities.

4. Sophisticate mathmatical approaches to interpreting trap data.

REPORT: C. TECHNOLOGY WORKSHOP REPORTER: D. D. Hardee
1. Delivery Systems

Introduction:

Delivery systems for semiochemicals can be one of the limiting factors in progressive research. Considerable progress has been made in this area, but major advances are continuing to provide the necessary vehicle for technology transfer with suppliers of formulated semiochemicals.

Selected ARS Accomplishments:

1. Development of effective delivery systems for several insect semiochemicals which are utilized in world-wide, as well as local, mass-trapping, mating disruption, monitoring, and other such programs.

2. Development of predictive models for release rates of numerous semiochemicals on various substrates.

3. Determination of performance criteria for semiochemical formulations provided by manufacturers.

4. Development of analytical techniques for determining emission rates of semiochemicals from numerous delivery systems.

5. Formation of a large knowledge base on semiochemicals and a successful track record for technology transfer through cooperative efforts of Federal, State, and industry personnel.

Current Research:

1. Continued evaluation of current and new delivery systems from ARS and State researchers, as well as those from industry.

2. Expansion and improvement of predictive models for release rates of semiochemicals.

3. Improvements in, and streamlining of, performance criteria provided to industry.

4. Development of improved analytical techniques for determining emission rates of semiochemicals with a wide range of volatility rates and from a large number of substrates.

Research Needs and Opportunities:

1. Develop performance criteria for delivery systems used in mating disruption.

2. Determine methods of stabilization of highly labile compounds.

3. Assemble and utilize dependable laboratory and field bioassays.

4. Incorporation of trapping devices and lures into one unit or system.

5. Develop improved substrates for compounds or mixtures with low and high molecular weights.

6. Continue and increase cooperative efforts with industry for development of effective delivery systems.

7. Determine optimum delivery rates and appropriate time(s) of delivery of semiochemicals.

8. Develop programmable delivery systems for semiochemicals.

REPORT: C. TECHNOLOGY WORKSHOP REPORTER: B. A. Leonhardt
2. Monitoring

Introduction:

Insect pheromones and attractants are highly useful for monitoring purposes. Some of these compounds are now used in ongoing management programs such as gypsy moth, boll weevil, Mediterranean fruit fly, California red scale, and others. Other biologically active materials are in the developmental stages. Delivery systems are required for effective utilization.

APHIS and the Forest Service are involved with several programs which typify utilization of monitoring systems. One program includes a very sophisticated detection system for gypsy moth which uses 300,000 pheromone-baited traps. New populations, once detected, are carefully mapped prior to application of control measures. This system works for a number of reasons which include definitive knowledge of % moths captured as a function of distance from emergence point, an effective trap/dispenser combination, and a definitive management strategy which utilizes the trapping data to make management decisions. This program serves as a model for the development of other such systems.

A second gypsy moth management program is designed to develop strategies to deal with natural spread of gypsy moth. A Forest Service Program emcompasses 13 million acres in Virginia and West Virginia and emphasizes low density management approaches. Pheromone-baited traps are key components of this program.

A third program, sponsored by APHIS, utilizes pheromone-baited traps to detect accidental introductions of one of about 14 exotic species, including the false codling moth, the Asiatic rice borer, and the summer fruit tortrix.

Selected ARS Accomplishments:

1. Discovery of numerous insect pheromones and utilization of these in management programs.

2. Development of the now-used commercial dispensers for the synthetic attractant (TML) of the medfly, the pheromone of the boll weevil, and other semiochemicals.

3. Utilization of monitoring systems for stored product pests.

4. Use of pheromone-baited traps for determination of insecticide resistance.

5. Measurement of insect distributions in time and space.

6. Development of new insect trap designs.

Current Research:

1. On-going pilot test for *H. zea* and *H. virescens* management.

2. Correlation of trap captures with insect populations as measured by independent methods. Examples include correlation of egg counts of Heliothis spp. with trap captures in a pilot test and use of traps baited with low doses of pheromone for estimating gypsy moth populations.

3. Identification of new male and female attractants.

4. Integration of plant volatiles with pheromones.

5. Examination of insect behavior with respect to trapping programs.

6. Development of effective delivery systems for complex mixtures of active compounds.

7. Refinement of currently used traps and dispensers.

Research Needs and Opportunities:

1. Focused efforts for research on important species not under current study.

2. Quantification of populations based on trap captures; correlation with reliable, independent estimates.

3. Refined interpretation trap data.

4. Development of criteria for active ingredients and dispensers.

5. Continued study of host plant/pest interactions.

6. Continued efforts to develop semiochemicals other than pheromones.

REPORT: C. TECHNOLOGY WORKSHOP
3. Mass Trapping/Baits

REPORTER: James R. Coppedge

Introduction:

The elimination of insects from a population by mass trapping or attractant and kill baits has considerable potential for the population redirection of some insect species. Effective systems require a good attractant and an effective way of capturing or killing the pests. This approach is the most effective when females (or both sexes) are attracted.

Selected ARS Accomplishments:

The Japanese beetle trap has proven effective in trapping out populations of this pests under certain conditions. The screwworm adult suppression system was developed by ARS. Gypsy moth, melon fly, Indian meal moth, and Oriental fruit fly are other examples. Swarm attractants have been developed for honeybees.

Current Research:

Current research which appears promising are attracticide systems for the boll weevil and the corn rootworm. Also, an attracticide is in the early stages of development for Heliothis.

Research Needs and Opportunities:

1. There is a need for more research on the basic insect biology and ecology, especially as it relates to semiochemicals.

2. There is a need for additional research on the activity of insects in different ecological systems.

3. Additional information is needed on trap design.

4. There is a need for more female insect attractants and food attractants.

5. Area-wide movement studies are needed for many species.

6. There is an increasing need for insect population modeling in relation to control by mass rapping or baits; stored product insects and the diamondback moth appear amendable to this control approach; the feasibility for using this approach in suppressing populations of soil dwelling insects should be investigated.

REPORT: C. TECHNOLOGY WORKSHOP
4. Mating Disruption

REPORTER: Peter E. A. Teal

Introduction:

The use of semiochemicals, primarily sex pheromones, for control of insect pests through mating disruption has been studied for a number of years. However, there have been few examples of successful, commercial applications of mating disruption for insect control. This is unfortunate because mating disruption has the potential to be a very effective alternative to chemical pesticides. The main reasons that mating disruption should be studied in greater detail are that it is species specific, environmentally sound, and being "natural" is more acceptable to consumers than the perceived over-use of chemical pesticides. Also, recent lowering of economic thresholds for several crops and loss of use of pesticides due to EPA restrictions are making mating disruption a more attractive means of insect control.

Selected ARS Accomplishments:

ARS scientists have made many significant contributions to the successes achieved in mating disruption, either directly by developing mating disruption systems for specific pests, or by providing significant basic information on which disruption systems have been developed. Major accomplishments include the following.

1. The development of a mating disruption system for the codling moth where it has been demonstrated that in closely monitored and controlled orchards fruit infestation can be decreased by 90 % over control plots.

2. The development of a mating disruption system to control attack by peachtree and lesser peachtree borers was pioneered and developed by ARS scientists and is now very close to registration for commercial use.

3. ARS scientists made significant contributions to the development of the mating disruption system currently in use to control the oriental fruit moth.

4. Significant contributions have been made by ARS scientists to the mating disruption program being undertaken by APHIS to control the pink bollworm in California and Arizona. This program promises to be an effective control technique when coupled with sterile insect release programs.

5. Basic studies conducted by ARS scientists which led to the identification of the sex pheromone of the tomato pinworm have allowed for the development of a highly effective mating disruption program currently in use for control of this pest in Mexico.

Current Research:

1. Characterization of the disruption of codling moth to partial and off ratio blends of pheromone.

2. Continued studies on the mechanism and efficacy of mating disruption for the peachtree and lesser peachtree borers.

3. Studies on the behavior of pink bollworm in pheromone permeated air.

4. Studies aimed at the development of a mating disruption system for the Mexican rice borer moth.

Research Needs and Opportunities:

1. The mechanisms which operate to effect mating disruption must be determined for each target insect. This will involve detailed studies on the basic pheromone mediated biology of the insects in response to complete, partial and off ratio blends of pheromone components.

2. Studies must be conducted on the behavior of insects in disruption and control plots to determine what the insects are doing in response to high levels of pheromone. These studies should include the behavior of both sexes.

3. There is a need to study the interaction between population density and the efficacy of mating disruption. What population levels can be controlled?

4. Studies aimed at determining those aspects of female movement that are pertinent to improving the efficacy of mating disruption should be undertaken.

5. There is a need to develop effective sampling methods for low population levels.

6. Techniques need to be developed that will allow for the implementation of changes to mating disruption systems currently in place without having to conduct large-scale field trails.

7. Studies should be conducted to define the area in which mating disruption will be effective.

8. Controlled release formulations need to be developed with increased effectiveness.

REPORT: C. TECHNOLOGY WORKSHOP
5. Semiochemicals-Plants

REPORTER: Richard Gueldner

Introduction:

Plants produce chemicals which affect insect behavior in various ways. These chemicals may be classed as attractants, repellents, feeding deterrents, oviposition stimulants or repellents, and as adjuvants to pheromones, and can be effective insect control agents.

Selected ARS Accomplishments:

1. Development of tobacco resistant to the tobacco budworm, tobacco hornworm, aphids, and tobacco that attracts the stilt bug; identification of the duvatriene diols as the common link in these plant/insect interactions.

2. Identification of oviposition stimulants and deterrents in tobacco.

3. Identification of maysin and chlorogenic acid as growth inhibitors/feeding deterrents of corn earworm and fall armyworm in corn silks and leaves.

4. Development of cotton resistant to *H. virescens*.

5. Patenting of azadirachtin, a natural product of the neem tree, for use in insect control.

Current Research:

Evaluation of insect growth inhibitors, feeding inhibitors, oviposition stimulants and deterrents, attractants and repellents from crop plants and non-host plants.

Research Needs and Opportunities:

1. Expand range of, and access to, bioassays to spot useful natural products.

2. Increase insect behavioral studies to assess effect and efficacy of natural products, and facilitate their development toward commercialization.

3. Assess effects of plant constituents in insect predators and parasites.

REPORT: C. TECHNOLOGY WORKSHOP REPORTER: J. H. Tumlinson
6. Semiochemicals - Beneficial Insects

Introduction:

Natural enemies (parasitoids and predators) are valuable resources for more effective and environmentally safe management of insect pests. Understanding the roles of semiochemicals and the mechanisms governing behavior responses of beneficial insects is essential to their effective utilization.

Selected ARS Accomplishments:

1. Demonstrated that semiochemicals play a vital role in (a) host location, recognition, acceptance and oviposition, and (b) courtship and mating in beneficial insects.

2. Demonstrated that plant (or other substrates) and host (or prey) chemicals are important, often in an interactive manner, in host location, acceptance, and oviposition in beneficial insects.

3. Demonstrated that beneficial insects often exploit pheromones and other semiochemicals for host (prey) location and attack.

4. Variations in beneficial insect responses to semiochemicals have been traced to (a) intraspecific genotypic variations, (b) learning, and (c) physiological state (e.g., hunger or mating status).

5. A number of sex pheromones and allelochemicals have been identified in beneficial insects and one (pheromone of the spined soldier bug) has been patented and licensed to a commercial company.

Current Research:

Programs targeted toward understanding pheromonal and allelochemical mediated behavior of beneficial insects are underway at several ARS locations. Substantial progress has been made toward demonstrating the potential value of semiochemicals for use in pest management with parasitoids and predators.

Research Needs and Opportunities:

To capitalize on the tremendous potential of parasitoids and predators for biological control of pest insects, research efforts leading to the understanding of the behavior and biology of these agents must be expanded.

1. Isolation, identification and synthesis of key pheromones and allelochemicals that mediate mating, foraging, and oviposition in beneficial insects is needed.

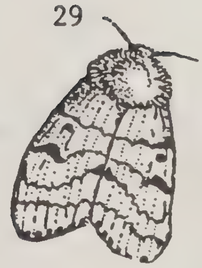
2. Elucidation of behavioral mechanisms involved in host (prey) location, recognition, and oviposition (attack) in beneficial insects is needed.

3. Determination of intrinsic variables (genotypic and phenotypic) and extrinsic (environment) variables that affect performance of parasitoids and predators.

4. Comparison of chemical-mediated behavior of parasitoids and predators in their natural ecosystem (e.g., wild host plants) with that in modern agroecosystems.

5. Integration of considerations of chemical-mediated foraging behavior of parasitoids and predators into plant breeding and crop management programs.

6. Development of technology for application of the above information in importation, augmentation, and conservation programs with beneficial insects.



REPORT: D. APPLICATIONS WORKSHOP
1. Crops/Monitoring-Lepidoptera

REPORTER: C. E. Rogers

Introduction:

Efficient detection and monitoring of populations are necessary for developing sound management strategies for lepidopterous pests. Semiochemicals have become a standard tool for monitoring populations of lepidopterous pests in most crops, as well as large-scale pest management/suppression programs.

Selected ARS Accomplishments:

ARS has clearly been a leader in developing semiochemical technology for monitoring insect pests, as well as in developing strategies for its use as research tools in area-wide suppression programs. ARS has been instrumental in identifying and developing semiochemicals as monitoring tools for the pickleworm, pink bollworm, beet armyworm, corn earworm, tobacco budworm, Mexican rice borer, pine tip moth, apple fruit moth, cranberry girdler, sunflower moth, banded sunflower moth, *Isophricitis similiella* and *Eucosoma womonana* in sunflower, and velvetbean caterpillar, among others.

Current Research:

ARS has numerous and varied programs investigating Lepidoptera semiochemicals.

1. Identification and perfection of pheromones for several species of armyworms.

2. Pheromone trap calibration for the corn earworm, tobacco budworm and others.

3. Use of semiochemicals for collecting specimens for specialized needs.

4. Use of semiochemicals for managing resistance to pyrethroids.

5. Correlation of trap catches with various population parameters.

6. Synergism between host volatiles and trap catches.

7. Identification of host and other attractants for female insects.

8. Improvement of gypsy moth and pink bollworm monitoring technology.

9. Use of semiochemicals for monitoring the peachtree borer and the lesser peachtree borer.

10. Use of semiochemicals in decision-making management of the pickleworm

11. Improvement of trap design/efficiency and blend optimization for monitoring the velvetbean caterpillar, soybean looper, and southern armyworm and other species

12. Use of semiochemicals for monitoring migration of the velvetbean caterpillar, black cutworm, fall armyworm, corn earworm, tobacco budworm, and others.

Research Needs and Opportunities:

In spite of the vast knowledge now available for lepidoptera semiochemicals, several research needs exist if this technology is to be of optimal benefit to agriculture in the future.

1. Fill voids between knowledge/technology development and clientele applications.

2. Improve trap designs/efficiency for several lepidopteran species.

3. Improve lepidopteran semiochemical formulations, release rates, lures/dispensers, placement, etc.

4. Anticipate and develop programs to meet changing grower's needs and environmental regulatory requirements.

5. Improve predictive efficacy of semiochemical technology; improve quality control and shelf-life of semiochemicals.

6. Improve integration of trap data and treatment and/or economic thresholds.

7. Delineate synergisms among host plants and semiochemicals.

8. Develop semiochemicals for monitoring lepidopteran females and/or immature stages.

9. Devise means for expediting technology transfer requirements for user applications.

REPORT: D. APPLICATIONS WORKSHOP
2. Crops Monitoring & Suppression-Lepidoptera

REPORTERS: J. Krysan
D. Light
P. Lingren

Introduction:

The use of lepidopteran sex pheromones has been widely and successfully applied for detection and survey of many different pests for determining the location and timing of management actions. Pheromone traps are rarely useful for determining economic thresholds or for the direct suppression of pests through mating disruption, mass trapping or attracticides. Exceptions include commercially applied mating disruption for control of oriental fruit moth, tomato pinworm, and pink bollworm. Promising plant-derived semiochemicals attractive to both sexes of Lepidoptera or for pheromone enhancement are beginning to appear. Further research is needed to elucidate the potential of these attractants and to bring commercially promising but refractory systems to fruition.

Selected ARS Accomplishments:

1. Identification of sex pheromones of numerous lepidopterous pests of cotton, corn, soybean, vegetables and fruit. The pheromones are widely used for detection and survey.

2. Contributions to the development of mating disruption for the pink bollworm, tomato pinworm and codling moth.

3. Important contributions to an understanding of the behavior and movement of insects, factors critical to the implementation of mating disruption, interpretation of monitoring data, and developments of new control strategies using other types of lepidopteran attractants.

4. Isolation of plant semiochemicals that attract noctuids in general and augment pheromone trap catch of codling moth and *Heliothis zea*.

5. Contributions to the use of pollen analysis for determining sources of migrating and low density insect pest populations, feeding host plant range, and possible sources of lepidopteran plant feeding attractants.

Current Research:

1. Studies on the effects of disruptant formulation on mating disruption of pink bollworm (Phoenix).

2. Isolation and characterization of plant volatile semiochemicals including studies of their interaction with lepidopteran sex pheromones (Lane, OK, College Station and Weslaco, TX, and Albany, CA) and the development of adult control technology utilizing attracticide baits.

3. Mating disruption of diamondback moth (Gainsville, FL and Yakima, WA), codling moth (Yakima, WA) and lesser peach tree borer (Byron, GA).

Research Needs and Opportunities:

1. Development of fundamental semiochemical-related knowledge of lepidopteran biology including chemoreception, behavioral responses, insect-host plant interactions, feeding behavior, phenology, and economic thresholds.

2. Monitoring and control technology based on identification and use of semiochemicals other than sex pheromones (e.g., aggregation, feeding, oviposition and currently unknown means of attraction) for lepidopteran insects.

3. Basic studies of insect movement using such techniques as lepidopteran female attractants, pollen analysis and doppler radar to formalize approaches to understanding movement and its effects on population dynamics in general and mating disruption, in particular.

4. Develop lepidopteran mating disruption and successfully incorporate it into IPM systems for key pests such as codling moth.

5. Explore mating disruption for control of selected lepidopteran pests for which inexpensive pheromones are available and prophylactic use of pesticides is common. Examples include leafrollers on fruit.

6. Carry out basic studies to subtend the development of pheromone and/or plant semiochemical traps to measure economic thresholds.

7. Optimize attractant and disruptant formulations for lepidopteran insects, both in quality/complexity of blend, and the rate and longevity of delivery.

REPORT: D. APPLICATIONS WORKSHOP REPORTER: Jim Coffelt
3. Stored-Product/Monitoring-
Lepidoptera, Coleoptera et al.

Introduction:

The use of semiochemicals in the stored-product environment to supplement conventional inspection and control methods has increased steadily in recent years. ARS scientists have discovered or contributed to the discovery and development of many of these materials. Exploitation of the extreme sensitivity of insects to semiochemicals is particularly appealing in the relatively closed stored-product environment.

Selected ARS Accomplishments:

1. Isolation, identification and behavioral analysis of more than a dozen stored-product insect pheromones.

2. Development of traps and detection/monitoring systems for stored product insects and the transfer of this technology to every segment of the production/marketing chain.

3. Demonstration that beetle larvae deposit kairomonal trails which host-specific parasitoids use to locate their hosts in stored products.

Current Research:

1. Isolation, identification and analysis of stored product insect pheromones and grain/food volatiles which function as pheromone synergists; study of parasitoid kairomones. (Madison, WI)

2. Determination of qualitative and quantitative factors that influence the effectiveness of pheromones of pyralid moths and anobiid beetles in the laboratory and warehouses; examination of host-produced materials that influence the behavior of anobiid beetles; identification of feral populations with sex pheromones. (Gainesville, FL)

3. Temporal analysis of odor profiles of on-farm stored wheat; behavioral and ecological analysis of interactions between stored-product insects and their parasitoids; physiological and ecological analysis of the defensive secretions of flour beetles. (Manhattan, KS)

4. Evaluation of commercial products for stored product insects. (Savannah, GA/Manhattan, KS)

5. Evaluation of synthetic bostrichid pheromones. (Beaumont, TX)

6. Identification of aggregation pheromones of nitidulid beetles. (Peoria, IL)

Research Needs and Opportunities:

1. Utilize semiochemicals for the development of efficient biological control strategies for stored product insects.

2. Develop optimum semiochemical lures for different stored product insect population densities and different insect tolerances associated with processed and unprocessed products.

3. Conduct fundamental behavioral and chemical studies relating to multi-trophic level semiochemical interactions in stored products.

4. Identify and characterize relationship(s) between trap captures and population levels in stored products.

5. Expand fundamental behavioral studies to develop understanding of how insects orient to semiochemical sources in the relatively still air of the stored product environment.

6. Isolate and identify host-produced chemicals that affect stored product insect behavior either directly or through interactions with other semiochemical stimuli.

7. Determine extent of, and measure fluctuations in, feral populations and determine their significance to stored-product insect control.

REPORT: D. APPLICATIONS WORKSHOP
4. Crops/Monitoring-Heteroptera, Homoptera, Hymenoptera

REPORTERS: J. Neal, J. Aldrich

Introduction:

Homoptera and Heteroptera (some 60,000 species) are more numerous than all the other insects having incomplete metamorphosis. Despite the many devastating crop pests in this group (see attachment) semiochemical research on these sucking insects lags far behind that for moths, beetles, and flies. For example, sex pheromones exist for only 6 scale and mealybug species and no synthetic pheromones are available for any plant-feeding heteropterans. Similarly, while the semiochemical knowledge of ants, bees, and social wasps has burgeoned, research on hymenopteran crop pests has not kept pace.

Selected ARS Accomplishments:

1. Aldrich et al. (1990, patent appl. no. 07/461,890), methyl (2E,4Z)-decadienoate for attraction of *Euschistus* spp.

2. Aldrich et al. (1990, U.S. patent no. 07/168,047), sesquiterpene epoxide pheromone components for *Nezara viridula*.

3. Kamm et al. (1990, 1987 & 1986), control of olfactory-induced behavior in alfalfa seed chalcid.

4. Oliver et al. (1990, 1987 & 1985) and Lusby et al. (1989 & 1987), novel acetogenins from *Stephanitis* and *Corythucha* spp. (Tingidae).

5. Aldrich et al. (1988), semiochemistry of three *Lygus* spp.

Current Research:

1. Alarm pheromones of tingids (J. Neal & J. Aldrich).

2. Semiochemical-mediated behavior of the alfalfa seed chalcid (J. Kamm).

3. Kairomones of *Lygus* and stink bugs (W. Jones & J. Aldrich).

4. Electroantennogram (EAG) bioassay for heteropteran pheromones (J. Aldrich & R. Dickens).

5. 1st-instar aggregation pheromone of *N. viridula* and other stink bugs (J. Aldrich).

6. Global mapping of *N. viridula* pheromone strains (J. Aldrich).

Research Needs and Opportunities:

Hemipterous insects present formidable challenges for semiochemists but, at the same time, offer unique opportunities for pest management. Their piercing-sucking mode of feeding and complex life cycles have hampered

research. However, many of these insects either have relatively long-lived, injurious adults or multiple generations per year, providing a potential for direct control tactics using pheromones. For example, spiking trap-crops with pheromones could increase the efficacy of this control strategy. Furthermore, hemipteran pheromones appear to have been extensively exploited by parasitoids as host-finding kairomones, and the Heteroptera include a large contingent of abundant and important predators. Thus, progress in the identification of hemipteran pheromones is potentially invaluable for the husbandry of beneficials. For hymenopteran crop pests, such as sawfly and chalcid pests of grain and seed, pheromones and host-volatiles mediate behavior but the semiochemicals remain unidentified. High-priority research needs and species are listed below. In particular, pheromones are urgently needed for *Lygus lineolaris* (tarnished plant bug) and its western congenor, *L. hesperus*. Since these polyphagous pests are difficult to sample, insecticide application for their control is excessive, and secondary pest resurgences frequently occur after attempts to suppress *Lygus* infestations with insecticides.

RESEARCH NEEDS	KEY SPECIES
1. Pheromone/kairomone identifications for key pests species.	Tarnished plant bug Southern green stink bug
2. Plant-volatiles mediating host-location by key species.	Sweetpotato whitefly Greenhouse whitefly
3. Electrophysiological bioassay capability.	Russian wheat aphid
4. Artificial diet for *Lygus lineolaris*.	Wheat stem sawfly
5. Commercially available trap for stink bugs.	Minute pirate bug

(Attachment to Report D4)

PESTS

HYMENOPTERA
- Chalcidae:
    - Bruchophagus roddi (alfalfa seed chalcid)
- Cynipidae:
    - Diplolepis spp. (gall wasps)
- Cephidae:
    - Cephus cinctus (wheat stem sawfly)

HETEROPTERA
- Miridae:
    - Lygus spp. (tarnished plant bug et al.)*
    - Campylomma verbasci (mullein bug)#
    - Pseudatomoscelis seriatus (cotton fleahopper)
    - Halticus bractatus (garden fleahopper)
- Pentatomidae:
    - Nezara viridula (southern green stink bug)*
    - Acrosternum hilare (green stink bug)*
    - Euschistus spp. (brown, onespotted, dusky, and consperse stink bugs)#
    - Murgantia histrionica (harlequin bug)
    - Thyanta accerra (redshouldered stink bug)
    - Chlorochroa sayi (Say's stink bug)
- Coreidae:
    - Anasa tristis (squash bug)
    - Leptoglossus spp. (leaf-footed bugs)
- Lygaeidae:
    - Blissus leucopterus (chinch bug)

HOMOPTERA
- Diaspididae:
    - Aonidiella aurantii (California red scale)#
    - Aonidiella citrina (yelcale)#
    - Quadraspidiotus pernicious (San Jose scale)#
    - Pseudaulacaspis pentagona (white peach scale)#
- Pseudococcidae:
    - Planococcus citri (citrus mealybug)#
    - Pseudococcus comstocki (Comstock mealybug)#
- Aphididae:
    - Diuraphis noxia (Russian wheat aphid)
    - Schizaphis graminum (greenbug)#
    - Acyrthosiphon pisum (pea aphid)#
    - Aphis fabae (black bean aphid)#
    - Myzus persicae (peach-potato aphid)#
    - Megoura viciae (vetch aphid)#
    - Sipha flava (yellow sugarcane aphid)
    - Therioaphis maculata (spotted alfalfa aphid)
- Aleyrodidae:
    - Trialeurodes vaporariorum (greenhouse whitefly)
    - Bemisia tabaci (sweetpotato whitefly)
    - Siphonius phillyreae (ash whitefly)

- Membracidae:
    Spissistilus festinus (threecornered alfalfa hopper)
- Cicadellidae:
    Empoasca fabae (potato leafhopper)

*Some presumed attractant pheromone compounds identified, but attraction to synthetics not demonstrated.
#Attraction to synthetics demonstrated in the laboratory and/or field.

REPORT: D. APPLICATIONS WORKSHOP
5. Crops/Monitoring & Suppression—Coleoptera

REPORTER: James R. Coppedge

Introduction:

The family Coleoptera contains some of the most economically important insects in the world. Attractants and traps have been developed for many of these pests. With additional research the potential for control systems appears excellent.

Selected ARS Accomplishments:

1. Development of trapping systems to detect and delineate populations of the boll weevil and the Japanese beetle.

2. Sex and food attractants have been identified for the corn rootworm, dried fruit beetles, and the dusky sap beetle.

Current Research:

Current research includes the development of attracticide systems for the boll weevil and the corn rootworm, the dried fruit beetle and the dusky sap beetle. Research is also underway to develop trapping systems for monitoring corn rootworm adults.

Research Needs and Opportunities:

1. There is a need for more information on the basic biology and ecology of many coleopterous pests.

2. There is a need for an attractant and/or a phagostimulant for the Colorado potato beetle and the pepper weevil.

3. There is a need for more information on food attractant-pheromone combinations for coleopteran pests.

4. There is a need for a better understanding of the mode of action of the Japanese beetle attractant.

REPORT: D. APPLICATIONS WORKSHOP
6. Crops/Feeding Deterrents - Lepidoptera, Coleoptera et al.

REPORTER: J. N. Jenkins

Introduction:

Most plants are not fed upon by most insects, i.e., they resist most insects. Feeding deterrents are probably involved. Many known plant compounds are insect feeding deterrents. Many of these are terpenoids and essential oils. The essential oils are often antimicrobial agents.

Selected ARS Accomplishments:

Neem research development and subsequent patenting of azadirachtin as margosan-o by Viking Ltd is a classic. The patent was later purchased by Grace Chemical Company and then owned by Grace-Sierra Company. Margosan-o is an insect deterrent as well as insect growth regulator. Margosan-o provides control of both sweet potato and greenhouse white flies, thrips, mealy bugs, leafminers, loopers, caterpillars, and gypsy moths on bedding plants, potted plants, foliage plants, ornamentals, trees, and shrubs in and around greenhouses, commercial nurseries and homes. Basic research into the mechanisms of resistance involving differences in resistant and susceptible germplasms developed in host plant resistance research has elucidated many deterrent compounds. Presently, host plant resistance programs in corn and cotton are yielding much information about deterrents. Current research on the azadirachtin from the Neem plant is yielding new and useful information.

New research is underway on a plant from China. Celastrus angulatus has yielded compounds that are effective deterrents. These deterrents are effective against grasshoppers and lepidoptera. One compound from this plant has been isolated and its chemical structure has been determined.

Research Needs and Opportunities:

1. There is a need to expand research on insect feeding and ovipositional deterrents.

2. Most plant species are resistant to more insects than they are susceptible; feeding deterrents are common in plants and need exploring.

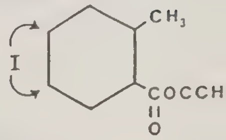
3. Deterrents that are applied to plants may have their greatest use on plants that develop a canopy quickly such as forest trees, ornamentals, fruit trees, etc., since new growth would not dilute the effectiveness of applied deterrents.

4. Deterrents can be used with annuals and row crops; however, it may be worthwhile to consider breeding the deterrent into these crops so they can deliver a continuous supply to new growth. In this way the deterrent is purchased with the seed.

5. An opportunity exists with some annuals that have precursors of deterrents. Genetic engineering of the enzyme gene into these plants could cause them to efficiently produce the deterrent. Increasing levels of maxsin in corn is an example of an application of approach.

REPORT: D. APPLICATIONS WORKSHOP
7. Crops/Monitoring & Suppression-Diptera: Tephritidae

REPORTERS: E. B. Jang
J. D. Warthen, Jr.
(C. Calkins, B. Leonhardt)



Introduction:

Tephritid fruit flies constitute one of the most economically important group of fruit-attacking insects. Their unique courtship activities must be considered when interpreting the results of their response to semiochemicals. Males produce the sex pheromone and both males and females respond to it during daylight hours. These species also use visual and acoustical cues before and during courtship that further complicate trapping results.

Selected ARS Accomplishments:

1. All of the attractants and techniques used worldwide today for control and eradication of tephritid fruit flies were developed by ARS scientists. *Dacus* and *Ceratitis* species respond to male attractants or parapheromones. These include the melon fly that is attracted to cuelure, the Oriental fruit fly and some other *Dacus* species that respond to methyl eugenol, and the medfly that responds to trimedlure (TML). A commercial controlled-release dispenser containing TML was developed and is now in use.

2. A more persistent attractant than TML was discovered for the medfly and patented (compound named ceralure); issuance of an exclusive license is in the final stages. The 8 isomers of TML and the 4 trans isomers of ceralure were isolated and their relative activities were characterized.

3. The papaya fruit fly pheromone was identified and synthesized. A trap using the pheromone and visual cues has been developed that catches virgin and mated females and some males.

4. Latilure has been discovered as an attractant for *Dacus latifrons*.

5. Computer molecular modeling was used to design alpha-copaene-like compounds which have medfly attractive properties.

6. The New World species, *Anastrepha*, was found to respond to food lures such as protein hydrolyzate, etc.

7. Progress has been made on identification of pheromone-host-formulation-trap interactions for papaya, Mediterranean, oriental fruit fly and *Anastrepha* spp.

Current Research:

1. Investigations into the sex pheromones of the papaya fruit fly and the medfly are continuing.

2. Field tests with the trapped components of fermenting fruit are being investigated for attraction to the Mexican fruit fly. These odors actually interfere with attraction when combined with the sex pheromones.

3. Attractancy of plant volatiles in combination with parapheromones is being studied. Identifications of host plant odors and their role in tephritid behavior, especially oviposition attractancy, are being investigated.

4. Structure-activity relationships of tephritid attractants are being investigated via synthesis and computer molecular modeling. Known and newly discovered attractants are being tested in the field.

5. Alternatives to aerial bait sprays for fruit flies, such as male annihilation techniques and chemically-defined food baits, are being investigated.

6. GC and HPLC analytical methods and confirming isomer-structure conformations are being developed for ceralure.

7. Formulations of TML and ceralure are being field tested for specific fruit flies.

Research Needs and Opportunities:

1. Develop a pheromone blend, dispenser and trap that will catch female medflies consistently.

2. Develop an improved dispenser for the pheromone of papaya fruit fly.

3. Develop ceralure/toxicant formulation that could be used in a male annihilation technique for medfly.

4. Determine the role of host-plant odors in attraction of female fruit flies alone and in combination with pheromones.

5. Determine the role of host fruit odors in attracting fruit fly females for oviposition.

6. Analyze pheromone responses and courtship behavior of economically important fruit flies in the laboratory and in the field.

7. Determine if pheromone component ratios of factory-reared fruit flies are identical to those of wild target flies when used in Sterile Insect Technique programs.

8. Design new tephritid attractants based on structures, such as alpha-copaene, with the help of computer modeling.

9. Evaluate new structues as alternatives to methyl eugenol as oriental fruit fly attractants.

10. Continue structure/activity studies on candidate synthetic attractants of tephritids.

11. Continue identification of pheromone components of *Anastrepha* spp.

REPORT: D. APPLICATIONS WORKSHOP REPORTER: A. DeMilo
8. Insects Affecting Man & Animals-Acarina, Hymenoptera, Diptera & Orthoptera

Introduction:

ARS has made substantial progress in the area of insect semiochemical and other behavior-modifying chemicals applicable to the development of repellents, pheromones and lures for filth flies, mosquitoes, screwworms and fire ants. Despite our success, it is becoming increasingly clearer that more research must be committed to these areas. Unfortunately, the emphasis and support provided to this type of research involving arthropods affecting man and animals is considerably less than that provided to similar research with crop pests, despite the fact that half the profits from American agribusiness comes from animals or animal related products. However, it is vital that we intensify our efforts since we are fast losing conventional control technologies for these medically-important arthropods. In this endeavor, we must develop alternative suppression techniques which are environmentally safe if we are to continue to produce sufficient meat and fiber as well as maintain human and animal health in the future at the same level as today.

Selected ARS Accomplishments:

1. Development of repellents for mosquitoes and various biting flies, e.g. Deet and its analogues.

2. Development of attractants and pheromones for pestiferous diptera of man and animals, e.g., Muscalure - house flies; Swarmlure - screwworm fly attractant; Swass - screwworm attractant plus toxicant for control.

3. Behavioral and chemical elucidation of the fire ant queen pheromone and worker produced recruitment pheromone.

4. Determined fire ant nestmate recognition mechanisms and applied this knowledge to parasites and to compare monogyne and polygyne fire ant populations.

5. Demonstrated the role of guanine as an assembly pheromone of argasid and Ixodid tick species; also identified a cholesterol oleate as a contrast mating pheromone of the American dog tick.

6. Development of a "decoy" system containing a cholesterol oleate, 2,6 - dichlorophenol and an acaricide, that provides effective control against the Lone star tick and American dog tick.

Current Research:

1. Studies to improve wind-oriented swarmlure traps for screwworm fly and other bait stations for potential use in developing countries in Central America and North Africa.

2. Isolation and characterization of screwworm wound attractants.

3. Laboratory and field behavior studies of screwworm wound materials that act as attractants.

4. Isolation and identification of screwworm mating-stimulant pheromone (female produced).

5. Synthesis and development of candidate carboxamide-derived repellents for cockroaches, ticks, mosquitoes and other biting flies and investigations of structure-activity relationships.

6. Studies in the behavior and population dynamics of cockroaches and the development of strategies for utilization of attractants and repellents for management of their populations.

7. Behavioral characterization of fire ant recruitment and queen pheromone in toxic bait formulations to develop better species specific fire ant baits that are environmentally acceptable.

8. Further characterization of fire ant queen pheromone chemistry.

9. Characterization of fire ant attractants in vegetable oils (soybeans, olive oil).

10. Studies on the characterization of semiochemicals given off by humans that attract mosquitoes and biting flies.

11. Studies on the characterization of sex attractants and sex stimulants of *Ixodes* spp. and other ticks.

12. Development of fire ant repellents.

13. Application of 1- octen-3- ol and other animal based attractants for tsetse flies and mosquitoes.

Research Needs and Opportunities:

There are numerous research opportunities on semiochemical and behavior modification chemistry that could provide more efficient control technologies for the suppression of arthropods affecting man and animals.

1. Development of species specific baits for fire ants and attractants for determining infestations and population levels of ants, cockroaches, biting and pestiferous flies, mosquitoes, ticks, etc.

2. Examine the potential of plant extracts as arrestants, attractants, and repellents of blood feeding insects.

3. Define host odors to determine host specificity for arthropods attacking man and animals.

4. Examine volatile pheromones for trapping systems of biting diptera for monitoring and control.

5. Explore the use of pheromones or semiochemicals to increase the efficiency of parasitoids and predators which attack pests of man and animals.

6. Increase emphasis on chemical structure-activity relationships in order to develop better and safer repellents for biting diptera and cockroaches.

7. Determine the optimal dosage response for attractants, pheromones, and repellents of arthropods affecting man and animals.

8. Increase field evaluation of semiochemicals and other behavior-modifying chemical formulations, so that the products can be transferred to the general public for controlling insects affecting man and animals.

9. Develop simulated models to determine potential impact of semiochemicals on control programs aimed at insects affecting man and animals.

10. Evaluate blends of pheromones with host-associated chemicals that elicit host-finding behavior for potential use in bait-toxicant systems to control the off-host stages of ticks. Investigate the array of pheromones that influence mating behavior of ticks.

11. Determine the triggering mechanism for pheromone biosynthesis and release and the biosynthetic pathway for pheromone synthesis with the goal of disrupting these processes and affecting control of insects affecting man and animals.

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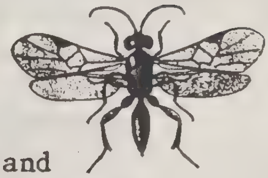
Determine the triggering mechanism for pheromone biosynthesis and release and the biosynthetic pathway for pheromone synthesis with the goal of disrupting these processes and effecting control of insects affecting man and animals.

REPORT: D. APPLICATIONS WORKSHOP
9. Beneficial Insects-Hymenoptera: Parasites & Predators

Reporters: R.L. Jones, J. H. Tumlinson



Introduction:

Parasitoids and predators are valuable resources for more effective and environmentally safe management of insect pests. To maximize the efficiency of these natural enemies they must be managed or manipulated in the field. This will require elucidation of the mechanisms and the semiochemicals that regulate the behaviors of these agents and the development of methods to use these semiochemicals in the field.

Selected ARS Accomplishments:

Considerable information regarding semiochemical-mediated behavior of parasitoids and predators has been developed in recent years. Also, there have been small scale demonstrations of the potential of semiochemicals to enhance the performance of these agents in the field. However, there have been no studies conducted on a large enough scale to allow evaluation and development of these approaches for practical pest control.

Current Research:

Further progress in field application is contingent upon advances resulting from the studies outlined in the Technology Workshop on Semiochemicals (Beneficial Insects), and in the development of economical in vitro mass rearing.

Research Needs and Opportunities:

1. Monitoring - Evaluation of natural enemy effectiveness requires population estimates. There is a need to identify pheromones and allomones and develop methods to use them effectively for monitoring populations of beneficial insects.

2. In vitro rearing - The development of practical in vitro rearing for beneficial insects requires the identification and use of proper chemical cues to induce oviposition or feeding in artificial substrates.

3. Quality control of mass reared beneficial insects - Methods need to be developed to use semiochemicals to monitor for genotypic and phenotypic variation in production colonies. Also, methods must be developed to condition mass reared beneficials with semiochemicals before their release.

4. Importation - The efficiency of imported beneficial insects can be markedly improved by the development and use of methods to screen these insects for proper behavioral characteristics and semiochemical responses before importation or release.

5. Augmentation - Methods must be developed to use semiochemicals to improve the effectiveness of beneficials in augmentation programs by conditioning or programming the insects to remain and search effectively in a target area after they are released.

6. Resource management - Methods need to be developed to use semiochemicals to manage endemic populations of beneficial insects in a particular field or area.

7. Multi-tactic approaches - Since some semiochemicals that influence the foraging behavior of natural enemies also function in other roles (e.g., as pheromones of the target hosts), it should be possible to develop an integrated control program that utilizes semiochemicals to manage the pest insects and their parasitoids or predators in the same area.

REPORT: D. APPLICATIONS WORKSHOP
10. Beneficial Insects-Hymenoptera: Honey Bees

REPORTERS: R.L. Jones, J. H. Tumlinson

Introduction:

Honey bees are important beneficial insects that contribute significantly to the U.S. economy via honey production and pollination. In recent years the industry has suffered from invasion by two species of parasitic mites and is currently threatened by the Africanized bee.

Selected ARS Accomplishments and Current Research:

Because they are social insects, honey bees use a wide variety of pheromones in colony management. Several of these pheromones have been identified from various glands of queen and worker bees, including several queen pheromones, the nasanov gland pheromone, and several alarm pheromones.

1. A queen pheromone, 9-oxo-E2-decenoic acid, is used to trap honey bee drones.

2. The nasanov pheromone is used to trap swarms of Africanized bees.

3. The nasanov pheromone is also used to attract bees for pollination.

4. An alarm pheromone, isopentyl acetate is used to test bees for defensiveness.

5. Analysis of the components of the alarm pheromones can differentiate between native and Africanized bees.

Research Needs and Opportunities:

1. A better queen pheromone blend is needed to improve methods of queen honey bee introduction and to control natural matings.

2. A better attractant is need to attract bees to crops in bloom for pollination.

3. A better attractant is needed for use in traps to capture swarms of Africanized bees for control purposes.

4. There is a need for good repellents to prevent honey bee swarms in inappropriate places.

5. There is a need for semiochemicals that can be used to reduce the defensiveness of honey bee colonies.

6. There is a need to identify pheromones or other semiochemicals that can be used to control parasitic mites.

REPORT: E. TECHNOLOGY TRANSFER OPPORTUNITIES REPORTERS: M. Inscoe
R. Ridgway

ARS Policy & Procedures: The use of patents, exclusive licensing, and cooperative agreements with the private sector can speed commercialization of new pest control technologies. In the past, without exclusive licenses for ARS inventions, there was little incentive for the private sector to invest in development of ARS inventions, and many ARS discoveries remained unused. With authority provided in the Technology Transfer Act of 1986 for issuing exclusive licenses for ARS-held patents, companies now have an expanded opportunity to recover their investments, and the number of patents being licensed has increased markedly. Inventions reported by ARS scientists have also been increasing, putting a major burden on the ARS patent program. Steps are being taken to reduce the backlog. However, it is the responsibility of the inventor to prepare and submit an Invention Report and consult with the patent advisor to document the invention as effectively as possible.

Other technology transfer tools available to the ARS scientist are memoranda of understanding and cooperative agreements, particularly the new Cooperative Research and Development Agreements (CRADA). These latter agreements were created specifically to involve the private sector in U. S. government research. They make it possible for ARS scientists and cooperators to share proprietary information, personnel, and equipment and for ARS to accept funds from the cooperator to further the research. CRADA's make possible the early involvement of cooperators in the research and the sharing of ownership of any patents that may result. Through these various technology transfer tools, products of ARS research are achieving commercialization more readily. The ARS Office of Cooperative Interactions, which is responsible for patent policy and facilitation of technology transfer, can provide ARS scientists with assistance in arranging cooperative studies and field tests, but the individual scientist continues to be the key person in technology transfer.

Panel Discussion by Industrial Representatives: A panel of representatives from four companies that are developing and marketing insect behavior-modifying products for insect management presented their views of mutual benefits that can be achieved through cooperation between the public and private sectors. There was common agreement that such cooperation can be very valuable to both parties. The importance of mutual involvement early in the research and the continued availability of the expertise and experience of the ARS inventor after a patent is licensed and the technology moves into the development stage was emphasized. Because of the specificity of behavior modifiers and because their applications are often as components of more complex management systems, markets are usually small and have limited profit potential. Therefore, a close cooperative relationship between the private and public sectors is essential if behavior modifiers are going to have a major impact. However, even minor products can be profitable if a company can predict and protect its market share.

REPORT: F. REGULATORY CONSIDERATIONS

REPORTERS: M. Inscoe
R. Ridgway

Introduction:

The major agency involved in the regulation of pesticides is the U.S. Environmental Protection Agency (EPA). By definition under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), a substance that is used to control or mitigate a pest is a pesticide. Pheromones and other behavior modifiers, when used for control of insects, are therefore pesticides and are regulated by EPA. Although some uses of pheromones have been exempted by EPA, it is important that every field test be at least examined to determine the need for regulatory approval. Under FIFRA, small tests (under 10 acres) usually do not require regulatory approval if the materials being tested are not used on food or feed crops. Generally, field tests on more than ten acres require experimental use permits (EUP's), and any material to be used on food or feed crops requires a tolerance or an exemption from tolerance if the crop is to be marketed. Data requirements for an EUP can be expensive, but waivers may be granted for some of these requirements, provided that adequate scientific rationale is provided. In certain specific circumstances, it is also necessary to comply with regulations of the Animal and Plant Health Inspection Service (APHIS) in running field tests. Under a cooperative agreement, a company can often provide expertise, help prepare documentation, and play an active role in obtaining regulatory approvals.

Discussion by Regulatory Agency Representative:

Ms. Anne Lindsay, Director of the Registration Division, Office of Pesticide Programs, EPA, presented an overview of the current registration process as it applies to insect behavior modifiers and discussed steps being taken to improve the process. EPA sees its role as providing the public (i. e., the consumer, its primary client) assurance of safety. The public is concerned about food safety and the environment and is demanding safer alternatives to conventional pesticides. The intent of EPA personnel is to be helpful, despite some opinions to the contrary. EPA recognizes the need to make the process work better and to improve communication. For credibility, EPA's actions must be based on firm information and scientific rationale.

EPA has recognized the inherent differences between conventional broad-spectrum pesticides and certain alternative means of pest control, and accordingly, under EPA policy, biological pesticides (including microbials, biochemicals, and transgenic plants) are treated somewhat differently from conventional pesticides. Biological pesticides are recognised as having relatively low toxicities and limited exposure potential, targeting specific pests, and having minor impact on the environment. There are about 32 biological pesticides registered, and five new registrations are expected soon. Recently, there has been a dramatic increase in applications.

For purposes of FIFRA, most behavior-modifying chemicals are classified as biochemicals, which are defined as naturally occurring substances or synthetic materials that are essentially identical in structure to the natural substances. EPA has authority to grant some exemptions, and it has been ruled that a pheromone product is exempt from registration if (1) it is labeled for use in a trap, (2) it is the sole active ingredient, and (3) its use will not significantly increase the concentration of the compound in the environment.

Since 1979, registration requirements for biological pesticides have been less than those for conventional insecticides. The target time for review of an application for biological pesticides is 280 days, about half that for other pesticides; however, this target can be met only if the application is complete. In general, data requirements are determined by the perceived potential risk in the use of a product. The components of risk include hazard and exposure; for biological pesticides, exposure is generally not expected to be a problem. Data requirements include (1) product analysis data (a critical part, which covers manufacturing process, unintentional ingredients, analytical methods, etc.) and (2) toxicity data. For biological chemicals a tier system has been established for toxicity data and materials with satisfactory Tier I data do not require further toxicity testing. Some toxicology data requirements are frequently waived provided adequate scientific rationale for the waivers is provided.

Although EPA has attempted to make the registration of biological pesticides easier, the feedback received indicates that there are still problems and a complete reexamination of the regulatory process is underway. Applicants can do much to make the process work better. Some steps suggested by Ms. Lindsay included:

1. Make use of a pre-application conference with the product manager to determine what data are needed in the application submission.

2. Write up a summary of decisions and recommendations made in this conference and check this with EPA to confirm that there is agreement as to the content of the meeting.

3. Be careful on quality control of the submission; EPA needs a legible, complete package.

4. Build sufficient time into plans. Although EUP's are moving faster, adequate review is still a time-consuming process.

5. Make calls to track progress of the submission and see whether there are problems that can be resolved.

6. Submit the application package directly to the product manager. Submissions to other EPA personnel only delay the start of the evaluation process.

EPA will be examining the regulatory process to determine where improvements can be made. Included will be areas such as general internal procedures, the use of generic EUP's to provide some flexibility in the

formulations used and the duration of the tests, and opportunities for additional exemptions from certain data requirements.

Additional perspectives on the registration process were provided by representatives of ARS cooperators. It was suggested that in some areas of non-food use, such as forestry, a substantial increase in acreage for field testing without an EUP would be appropriate. Also, the possibility of using structure-activity relationships to predict potential toxicological effects of certain classes of compounds where substantial data are available was suggested as an approach to reducing data requirements. The influence of the inherent small market size on the development and registration of the highly selective behavior-modifying chemicals was highlighted. For instance, because of the small market size, regulatory costs must be kept at a minimum. Further, the small market size apparently is not understood by those in EPA that are calculating re-registration fees, because these fees, at least in some cases, appear to be inconsistent with market size. Finally, because most of the behavior modifiers are being developed by small specialty companies, delays in obtaining action from regulatory agencies are particularly burdensome and in some cases may very well be a determining factor in the success of the company.

V. APPENDICES

APPENDIX A. DEFINITIONS[1]

Allelochemical - A substance significant to organisms of a species different from its source, for reasons other than food as such.

Allomone - A substance produced or acquired by an organism which, when it contacts an individual of another species in the natural context, evokes in the receiver a behavioral or physiological reaction adaptively favorable to the emitter but not the receiver.

Apneumone - A substance emitted by a nonliving material that evokes a behavioral or physiological reaction adaptively favorable to a receiving organism, but detrimental to an organism of another species, which may be found in or on the nonliving material.

Arrestant - A chemical which causes an organism to aggregate in contact with it, the mechanism of aggregation being kinetic or having a kinetic component. An arrestant may slow the linear progression of the organism by reducing actual speed of linear progression, but reducing actual speed of locomotion, or by increasing the turning rate.

Attractant - A chemical which causes an organism to make oriented movements toward its source.

Deterrent - A chemical which inhibits feeding, mating, or oviposition when in a place where an organism would, in its absence, feed, mate, or oviposit.

Hormone - A chemical agent produced by a tissue or an endocrine gland that controls various physiological processes within an organism.

Kairomone - A substance produced or acquired by an organism which, when it contacts an individual of another species in the natural context, evokes in the receiver a behavioral or physiological reaction adaptively favorable to the receiver but not the emitter.

Pheromone - A substance that is secreted by an organism to the outside that causes a specific reaction in a receiving organism of the same species.

Repellent - A chemical which causes an organism to make oriented movements away from its source.

Semiochemicals - Chemicals involved in the chemical interaction between organisms; chemicals emitted and/or produced by one organism that affect another organism; behavior-modifying chemicals; naturally-occurring, message-bearing compounds used by organisms for communication.

Stimulant - (a) Locomotor stimulant: a chemical which causes, by a kinetic mechanism, organisms to disperse from a region more rapidly than if the area did not contain the chemical. (b) Feeding, Mating, or Ovipositional stimulant: a chemical which elicits feeding, mating, or oviposition in an organism. Feeding stimulant is synonymous with the term phagostimulant.

Synomone - A substance produced or acquired by an organism which, when it contacts an individual of another species in the natural context, evokes in the receiver a behavioral or physiological reaction adaptively favorable to both emitter and receiver.

Synthetic behavior modifiers - Substances produced by humans and not of known natural origin.

1/ After, in part, Nordlund, D. A., and W. J. Lewis. 1976. Terminology of chemical releasing stimuli in intraspecific and interspecific interactions. J. Chem. Ecol. 2:211-20.

APPENDIX B. COMMITTEE MEMBERSHIPS

INSECT SEMIOCHEMICALS: OPPORTUNITIES AND CONSTRAINTS FOR DEVELOPMENT AND USE

ARS Planning Workshop

Steering Committee

R. Ridgway
Beltsville, MD

J. Lewis
Tifton, GA

R. Heath
Gainesville, FL

W. Snow
Byron, GA

R. Flath
Albany, CA

R. Patterson
Gainesville, FL

J. Coppedge
Beltsville, MD

R. Faust
Beltsville, MD

Report Committee

R. Faust
Beltsville, MD

J. Coppedge
Beltsville, MD

H. Oberlander
Gainesville, FL

R. Ridgway
Beltsville, MD

R. Patterson
Gainesville, FL

J. Krysan
Yakima, WA

C. Rogers
Tifton, FL

R. Flath
Albany, CA

B. Leonhardt
Beltsville, MD

J. Lewis
Tifton, GA

Registration and Local Arrangements Committee

W. Snow
Byron, GA

J. Coppedge
Beltsville, MD

R. Mayhew
Beltsville, MD

D. Hyde
Athens, GA

APPENDIX C. CONFERENCE AGENDA

INSECT SEMIOCHEMICALS:

OPPORTUNITIES AND CONSTRAINTS FOR DEVELOPMENT AND USE

ARS Planning Workshop

Holiday Inn - Airport South
5010 Old National Highway
Atlanta, GA 30349
(404) 761-4000

May 7-10, 1990

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Agricultural Research Service

U. S. Department of Agriculture

INSECT SEMIOCHEMICALS: OPPORTUNITIES AND CONSTRAINTS FOR DEVELOPMENT AND USE

Program Summary

Opening Session, Tuesday, May 8.

8:00 a.m.
- Welcome
- Objectives and Charge
- Needs for Alternative Methods of Insect Control
- Insect Chemistry
- Plant Chemistry
- Population Ecology
- Workshop Guidelines

	Session A	Session B	Session C
Workshop I -- Science, Tuesday, May 8.			
1:15 p.m.	1. Bioregulation	3. Chemistry (Insects)	5. Behavior
3:00 p.m.	2. Perception	4. Chemistry (Plants)	6. Population Dynamics
Workshop II --Technology, Wednesday, May 9.			
8:15 a.m.	1. Delivery Systems	3. Mass Trapping/ Baits	5. Semiochemicals (Plants)
10:15 a.m.	2. Monitoring	4. Mating Disruption	6. Semiochemicals (Beneficial Insects)
Workshop III -- Applications, Wednesday, May 9.			
1:15 p.m.	1. Crops/Monitoring (Lepidoptera)	1. Crops/Monitoring and Suppression (Coleop.)	1. Animals (Acarina, Hymen., Dipt.,Orthop.)
2:05 p.m.	2. Crops/Monitoring and Suppression (Lep.)	2. Crops/Feeding Deterrents (Lep.,Col.)	2. Animals (Acarina, Hymen., Dipt.,Orthop.) (contd.)
3:15 p.m.	3. Stored Products/ Monitoring (Lep., Coleop., etc.)	3. Crops/Monitoring and Suppression (Diptera: Tephritidae)	3. Beneficial Insects (Hymenoptera)
4:05 p.m.	4. Crops/Monitoring (Hemip., Homop., Hymenop., etc.)	4. Crops/Monitoring and Suppression (Diptera: Tephritidae) (contd.)	4. Beneficial Insects (Hymenoptera) (contd.)

Closing Session, Thursday, May 10.

8:00 a.m.
- Technology Transfer Opportunities
- Regulatory Considerations
- Summary Reports and Closing Remarks

INSECT SEMIOCHEMICALS: OPPORTUNITIES AND CONSTRAINTS FOR DEVELOPMENT AND USE

ARS Planning Workshop

May 7-10, 1990

Monday, May 7

Registration — Lobby

3:00-7:00 p.m.

Planning Meeting — Pine Room

7:30 p.m.	Steering and Report Committees, Moderators, Reporters, and Co-Organizers		

Tuesday, May 8

Registration — Outside Oak Room II

7:00-11:00 a.m.

Opening Session — Oak Room II

Moderator: J. Coppedge

8:00 a.m.	Welcome	-	E. Corley
8:15	Objectives and Charge to the Workshop	-	R. Faust
8:30	Needs for Alternative Methods of Insect Control	-	M. Mellinger
9:15	Insect Chemistry	-	R. Cardé
10:00	Break		

Moderator: J. Lewis

10:15	Plant Chemistry	-	H. Cutler
11:00	Population Ecology	-	P. Price
11:45	Workshop Guidelines	-	R. Ridgway
12:00 noon	Lunch		

Workshop I - Semiochemical Science: Molecules, Organisms, and Populations
(additional discussants may be added)

Tuesday, May 8

Science A — Oak Room I

1:15 p.m.	Science A 1. Bioregulation	Introductory Paper: Moderator: Reporter: Discussants:	- A. Raina - J. Menn - H. Oberlander - L. Miller - P. Teal et al.
3:00	Break		
3:15	Science A 2. Perception	Introductory Paper: Moderator: Reporter: Discussants:	- J. Dickens - H. Oberlander - J. Menn - J. Klun - S. Meyer et al.
5:00	Adjourn		

Science B — Oak Room II

1:15 p.m.	Science B 3. Chemistry (Insects)	Introductory Paper: Moderator: Reporter: Discussants:	- J. Tumlinson - R. Heath - O. Chortyk - D. Carlson - R. Bartelt et al.
3:00	Break		
3:15	Science B 4. Chemistry (Plants)	Introductory Paper: Moderator: Reporter: Discussants:	- R. Flath - O. Chortyk - R. Heath - P. Hedin et al.
5:00	Adjourn		

Science C — Pine Room

1:15 p.m.	Science C 5. Behavior	Introductory Paper Moderator: Reporter: Discussants:	- P. Landolt - J. McLaughlin - C. Rogers - A. Collins et al.
3:00	Break		
3:15	Science C 6. Population Dynamics	Introductory Paper: Moderator: Reporter: Discussants:	- E. Mitchell - C. Rogers - J. McLaughlin - J. Hayes et al.
5:00	Adjourn		

Pool Side

6:00	Attitude Adjustment		

Oak Ballroom

7:30	Dinner Moderator Keynote Address		 - R. Burns - L. Davis Univ. of Georgia

Workshop II - Technology: Approaches to Utilization
(additional discussants may be added)

Wednesday, May 9

Technology A — Oak Room I

8:15 a.m.	Technology A 1. Delivery Systems	Introductory Paper: Moderator: Reporter: Discussants:	- B. Leonhardt - L. McDonough - D. Hardee - R. Heath et al.
10:00	Break		
10:15	Technology A 2. Monitoring	Introductory Paper: Moderator: Reporter: Discussants:	- C. Schwalbe - R. Heath - B. Leonhardt - J. Lopez et al.
12:00 noon	Lunch		

Technology B — Oak Room II

8:15 a.m.	Technology B 3. Mass Trapping/Baits	Introductory Paper: Moderator: Reporter: Discussants:	- D. Lance - P. Teal - J. Coppedge - J. Smith et al.
10:00	Break		
10:15	Technology B 4. Mating Disruption	Introductory Paper: Moderator: Reporter: Discussants:	- J. Krysan - W. Snow - P. Teal - R. Staten - K. Thorpe et al.
12:00 noon	Lunch		

Technology C — Pine Room

8:15 a.m.	Technology C 5. Semiochemicals (Plants)	Introductory Paper: Moderator: Reporter: Discussants:	- G. Daterman - R. Flath - R. Gueldner - R. Severson et al.
10:00	Break		
10:15	Technology C 6. Semiochemicals (Beneficial Insects)	Introductory Paper: Moderator: Reporter: Discussants:	- J. Lewis - R. Jones - J. Tumlinson - R. Cardé et al.
12:00 noon	Lunch		

Workshop III --Applications: Opportunities and Needs for Expanded Use
(discussants may be added)

Wednesday, May 9

Applications A — Oak Room I

1:15 p.m.	Applications A 1. Crops/ Monitoring (Lepidoptera)	*J. Klun *C. Rogers K. Elsey E. Mitchell J. McLaughlin
2:05	Applications A 2. Crops/ Monitoring and Suppression (Lepidoptera)	*J. Krysan *P. Lingren T. Henneberry W. Wolf
2:55	Break	
3:15	Applications A 3. Stored Products/ Monitoring (Lepidoptera, Coleoptera, etc.)	*W. Burkholder *R. Howard J. Coffelt K. Vick M. Mullen R. Mankin
4:05	Applications A 4. Crops/ Monitoring (Heteroptera, Homoptera, Hymenoptera, etc.)	*J. Aldrich *K. Elsey W. Jones J. Kamm G. Snodgrass J. Neal
4:55	Adjourn	

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* Co-Organizers: These persons have the option of making a brief introductory presentation; they will select discussants to make 5 minute presentations to serve as the basis of discussion, will designate a reporter to prepare a 1-2 page report, and will moderate the session.

Workshop III -- Applications: Opportunities and Needs for Expanded Use
(discussants may be added)

Wednesday, May 9

Applications B — Oak Room II

1:15 p.m.	Applications B 1. Crops/ Monitoring and Suppression (Coleoptera)	*J. Coppedge *D. Lance Wm. Cantello T. Ladd J. Smith R. Bartelt M. Klein
2:05	Applications B 2. Crops/ Feeding Deterrents (Lepidoptera, Coleoptera)	*J. Jenkins *H. Cutler P. Hedin R.Gueldner D. Warthen N. Wakabayashi
2:55	Break	
3:15	Applications B 3. Crops/ Monitoring and Suppression (Diptera, Tephritidae)	*C. Calkins *B. Leonhardt R. Cunningham P. Landolt N. Wakabayashi D. Robacker D. Warthen A. DeMilo R. Heath E. Jang D. Light
4:05	Applications B 4. Crops/Monitoring and Suppression (Diptera, Tephritidae), contd.	(same as above)
4:55	Adjourn	

* Co-Organizers: These persons have the option of making a brief introductory presentation; they will select discussants to make 5 minute presentations to serve as the basis of discussion, will designate a reporter to prepare a 1-2 page report, and will moderate the session.

Workshop III --Applications: Opportunities and Needs for Expanded Use
(discussants may be added)

Wednesday, May 9

Applications C — Pine Room

1:15 p.m.	Applications C 1. Animals (Acarina, Hymenoptera, Diptera, and Orthoptera)	*R. Patterson *J. Whitten L. Hammack R. Vander Meer D. Carlson A. DeMilo R. Brenner
2:05	Applications C 2. Animals (Acarina, Hymenoptera, and Diptera), contd.	(same as above)
2:55	Break	
3:15	Applications C 3. Beneficial Insects (Hymen optera)	*J. Lewis *J. Tumlinson R. Jones P. Greany A. Collins Wm. Nettles
4:05	Applications C 4. Beneficial Insects (Hymen optera) (contd.)	(same as above)
4:55	Adjourn	

* Co-Organizers: These persons have the option of making a brief introductory presentation; they will select discussants to make 5 minute presentations to serve as the basis of discussion, will designate a reporter to prepare a 1-2 page report, and will moderate the session.

Wednesday, May 9

6:00	Dinner (on your own)	
7:30	Preparation of Summary Reports	

Thursday, May 10

Closing Session — Oak Room II

Moderator: R. Ridgway
Reporter: M. Inscoe

8:00 a.m.	Technology Transfer Opportunities	- Richard Parry
	Industrial Representatives Panel	- Owen Jones AgriSense - Staffan Lindgren PheroTech - Philip Kirsch BioControls Ltd. - Charles Doane Scentry
9:00	Regulatory Considerations	
	- Guidelines for ARS Scientists	- Richard Parry
	- Opportunities for Improving the Process	- Anne Lindsay EPA
	- Perspectives from the Forest Service	- Max Ollieu FS
	- Perspectives from the Private Sector	- Ian Weatherston Tech. Services Group
10:15	Break	

Moderator: R. Faust

10:30 a.m.	Summary Reports	
	Science	
	– Bioregulation / Perception	J. Menn
	– Chemistry	R. Heath
	– Behavior / Population Dynamics	C. Rogers
	Technology	
	– Delivery Systems / Monitoring	B. Leonhardt
	– Mass Trapping / Mating Disruption	P. Teal
	– Semiochemicals	R. Flath
	Opportunities and Needs for Problem Solving	
	– Crop Pests	J. Coppedge
	– Stored Product Pests	W. Burkholder
	– Man and Animal Pests	R. Patterson
	– Beneficial Insects	J. Tumlinson
	Discussion	
	Closing Remarks	R. Faust
12:30 p.m.	Adjourn	

Committees — Oak Room II

1:30	Steering and Report Committees Meeting	

APPENDIX D. LIST OF PARTICIPANTS

ARS INSECT SEMIOCHEMICAL WORKSHOP
Atlanta, Georgia
May 7-10, 1990

Dr. Jeffrey Aldrich
USDA/ARS/BA
Bldg 467, BARC-EAST
Beltsville, MD 20705

Dr. Mike Banfield
Consep Membranes Inc.
P.O. Box 6059
Bend OR. 07708

Dr. Robert Bartelt
USDA/ARS/MWA
1815 N. University
Peoria, IL 61604

Dr. R Bartlett
Fermon Chemicals Inc.
1700 N. 7th Ave.Suite 100
Phoenix, AZ 85007

Dr. Keith Bramley
Micro Flo. Co.
P.O. Box 5948
Lakeland, Fl 33807

Dr. Richard Brenner
USDA/ARS/SAA
1700 SW 23RD DR
P.O. Box 14565
Gainesville, FL 32604

Dr. David Brown
3706 W. Nob Hill Blvd.
Yakima, WA 98902

Dr Wendell Burkholder
USDA/ARS/MWA
1925 Linden Dr., West
Madison, WI 53706

Dr. Robert Burns
USDA/ARS/SAA
P. O. Box 5677
Athens, GA 30613

Dr. Carrol Calkins
USDA/ARS
1700 S.W. 23rd Drive
Gainesville, FL 32604

Dr. Bruce Campbell
USDA/ARS
Western Regional Res. Ctr.
800 Buchanan Street
Albany, CA 94710

Dr. William Cantelo
USDA/ARS/BA
Bldg 004, BARC-WEST
Beltsville, MD 20705

Dr. Ring Carde
Dept. of Entomology
Univ. of Massachusetts
Amherst, MA 01003

Dr. David Carlson
USDA/ARS
P.O. Box 14565
Gainesville, FL 32604

Dr. Orestes Chortyk
Tob.Qual.&Safety Res.Unit
P.O. Box 5677
Athens, GA 30613

Dr. James Coffelt
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Anita Collins
USDA/ARS
2413 E. Highway 83
Bldg. 205
Weslaco, TX 78596

Dr. John Cook
AgriSense
4230 West Swift, Suite 106
Fresno, CA 93722

Dr. James Coppedge
USDA/ARS/NPS
Bldg 005, Rm 212,
Beltsville, MD 20705

Dr. E. Corley, Jr.
USDA/ARS/SAA
P. O. Box 5677
Athens, GA 30613

Dr. Horace Cutler
USDA/ARS/SAA
P. O. Box 5677
Athens, GA 30613

Dr. Roy Cunningham
USDA/ARS
P.O. Box 4459
Hilo, HI 96720

Dr. G. Daterman
Forest Sciences Lab.
3200 S.W. Jefferson Way
Corvallis, OR 97331

Dr. L. Davis
Dept of Entomology
Univ of Georgia
Athens, GA 30602

Dr. Albert DeMilo
USDA/ARS/BA
Room 10, Bldg 010
Beltsville, MD 20705

Dr. Joseph Dickens
USDA/ARS/MSA
P. O. Box 5367
Mississippi State, MS 39762

Dr. C. Doane
26405 Weat Highway 85
P.O. Box 426
Buckeye, AZ 85326

Dr. Robert Doolittle
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Pat Dowd
USDA/ARS/MWA
1815 N. University
Peoria, IL 61604

Dr. Fred Eller
ARS
Peoria, IL

Dr. Kent Elsey
U. S. Vegetable Lab.
2875 Savannah Highway
Charleston, SC 29414

Dr. Gary Elzen
USDA/ARS/MSA
Delta State Res. Ctr.
P. O. Box 346
Stoneville, MS 38776

Dr. Kenneth Farminer
AgriSense
4230 west Swift, Suite 106
Freson, CA 93722

Dr. Robert Faust
USDA/ARS/NPS
Bldg 005, Rm 232
Beltsville, MD 20705

Dr. Steven Ferkovich
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Robert Flath
USDA/ARS
Western Regional Res. Ctr.
800 Buchanan Street
Albany, CA 94710

Dr. Patrick Greany
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. T Green
Pest Management Supply
P.O. Box 938
Amherst, MA 01004

Dr. R. Gueldner
USDA/ARS/RRC
Tob.Qual.& Safety Res.Unit
P.O. Box 5677
Athens, GA 30613

Dr. Dennis Hamel
USDA Forest Service
12th and Independent, S.W.
P.O. Box 96090
Washington, D.C. 20090-6090

Dr. Leslie Hammack
USDA/ARS/NPA
Bioscience Research Lab
P.O. Box 5674
Fargo, ND 58105

Dr. Dick Hardee
USDA/ARS/MSA
P. O. Box 346
Stoneville, MS 38776

Dr. Jane Hayes
USDA/ARS/MSA
P. O. Box 346
Stoneville, MS 38776

Dr. Robert Heath
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Paul Hedin
USDA/ARS
Boll Weevil Research Lab.
P.O. Drawer 5367
Mississippi State, MS 39762

Don Hendricks
USDA/ARS
Cotton Insects Res.
Stoneville, MS 38776

Thomas Henneberry
USDA, ARS, PWA
4135 E. Broadway Road
Phoenix, AZ 85040

Dr. Ralph Howard
U.S. Grain Mktg. Res.Lab
1515 College Ave.
Manhattan, Kansas 66502

Dr. Franklin Howell
USDA/ARS
3706 W. Nob Hill Blvd.
Yakima, WA 98902

Dr. May Inscoe
USDA/ARS/BA
Room 205, Bldg. 402
Beltsville, MD 20705

Dr. Eric Jang
USDA/ARS/PWA
P.O. Box 4459
Hilo, HI 96720

Dr. Johnie Jenkins
USDA/ARS/MSA
P. O. Box 5367
Mississippi State, MS 39762

Dr. Walker Jones
Carl Hayden Bee Res. Ctr.
2000 E. Allen Rd.
Tucson, AZ 85719

Dr. O. Jones
AgriSense-BCS Ltd
Mid Glamorgan, UK

Dr. Richard Jones
Dept. Of Entomology
Univ. of Minnesota
1980 Fowell Ave
St Paul, MN 55108

Dr. James Kamm
USDA/ARS/PWA/NFSPRC
Oregon State Univ.
3450 S.W. Campus Way
Corvallis, Oregon 97333

Dr. John Kennedy
John W. Kennedy Consultants
9101 Cherry Ln., Suite 113
Laural, MD 20708-1133

Dr. Philipp Kirsh
Biocontrol LTD
719 Second St. Suite 12
Davis, CA 95616

Dr. Michael Klein
USDA/ARS/MWA
Ohio Agri.Lab/Hort.Ins.Lab.
Wooster, OH 44691

Dr. J. Klun
USDA/ARS
Room 203, Bldg. 309
Beltsville, MD 20705

Dr. Alan Knight
USDA/ARS
3706 W. Nob Hill Blvd.
Yakima, WA 98902

Dr. James Krysan
USDA/ARS
3706 W. Nob Hill Blvd.
Yakima, WA 98902

Dr. Thyril Ladd, Jr.
USDA/ARS/MWA
Ohio Agri. Ctr./Hort.Ins.Lab.
Wooster, OH 44691

Dr. David Lance
USDA/ARS/NPA
RR 3
Brookings, SD 57006

Dr. Peter Landolt
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Barbara Leonhardt
USDA/ARS/BA
Room 165, Bldg. 011A
Beltsville, MD 20750

Dr. Joe Lewis
USDA/ARS
P.O. Box 748
Tifton, GA 31793

Dr. Y.-S. Li
USDA/ARS/MWA
P.O. Box 7629
Research Park, Route K
Columbia, MO 65205

Dr. Douglas Light
USDA/ARS/PWA
800 Buchanan Street
Albany, CA 94710

Dr. Peter Lingren
USDA/ARS/SPA
Hwy 3, West
Lane, OK 74555

Dr. S. Lindgren
Phero Tech Inc.
1140 Clark Dr.
Vancouver, B.C.
Canada V5L #K3

Dr. Anne Lindsay
Environmental Prot. Agency
401 M Street., S.W.-H7505
Washington, DC 20460

Dr. William Lingren
Trece Inc.
645 South Sanborn Rd.
P.O. Box 5267
Salinas, CA 94901

Dr. Juan Lopez
USDA/ARS/SPA/A&M Univ.
Rm 231, Ag Eng. Bldg.
College Station, TX 77843

Dr. Robert Lynch
USDA/ARS/SAA
P. O. Box 748
Tifton, GA 31793

Dr. Richard Mankin
USDA/ARS/IABBBRL
1700 S.W. 23rd Drive
Gainesville, FL 32604

Dr. V. Mastro
USDA APHIS
Otis AFB
Otis MA 02542

Dr. Sidney Mayer
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Heather McAuflane
Dept. of Entomology
Texas A & M
College Station
TX 77843-2475

Dr. Les McDonough
USDA/ARS
3706 W. Nob Hill Blvd.
Yakima, WA 98902

Dr. John McLaughlin
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Madeline Mellinger
Glades Crop Care
949 Turner Quay
Jupiter, FL 33458

Dr. Julius Menn
USDA/ARS/BA
Bldg 003, BARC-WEST
Beltsville, MD 20705

Dr. Steve Miller
USDA/ARS/IABBBRL
P. O. Box 14565
Gainesville, FL 32604

Dr. Lois Miller
Dept of Entomology
Univ of Georgia
Athens, GA 30602

Dr. Everett Mitchell
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. D. Mueller
Insects Limited Inc.
P.O. Box 40641
10505 N. College Ave.
Indianapolis, IN 46280

Dr. Michael Mullen
USDA/ARS
Stored-Product Ins.R&D Lab.
P.O. Box 22909
Savannah, GA 31403

Dr. John Neal, Jr.
USDA/ARS
Bldg. 470
Beltsville, MD 20705

Dr. William Nettles, Jr.
USDA/ARS
2301 S. International Blvd.
Weslaco, TX 78596

Dr. Herbert Oberlander
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Max Ollieu
USDA Forest Service
12th and Independent, S.W.
P.O. Box 96090
Washington, D.C. 20090-6090

Dr. Richard Parry
USDA/ARS/OCI
Bldg. 005, Rm. 102
Beltsville, MD 20705

Dr. Richard Patterson
USDA/ARS/SAA
P. O. Box 14565
Gainesville, FL 32604

Dr. Jerry Payne
USDA/ARS/SAA
P. O. Box 87
Byron, GA 31008

Dr. Peter Price
Dept. of Biology
Northern Arizona Univ.
Flagstaff, AZ 86001

Dr. Burt Quisumbing
Hercon Environmental Co.
P.O. Box 786
York, PA 17405

Dr. Ashok Raina
USDA/ARS/BA
Room 101, Bldg. 402
Beltsville, MD 20705

Dr. Richard Rice
Kearney Agri. Ctr.
Univ. of California
Parlier, CA 93648

Dr. Richard Ridgway
USDA/ARS/BA
Room 107, Bldg. 402
Beltsville, MD 20705Dr.

Dr. David Robacker
USDA/ARS
2301 S. International Blvd.
Weslaco, TX 78596

Dr. Charlie Rogers
USDA/ARS/IBPMRL
P.O. Box 748
Tifton, GA 31793-0748

Dr. R. Schalk
U. S. Vegetable Lab.
2875 Savannah Highway
Charleston, SC 29414

Dr. W. Schlotzhauer
USDA/ARS/RRC
Tob.Qual.&Safety Res.Unit
P.O. Box 5677
Athens, GA 30613

Dr. C. Schwalbe
USDA APHIS
Otis AFB
Otis MA 02542

Dr. Ray Severson
USDA/ARS/RRC
Tob.Qual.&Safety Res.Unit
P.O. Box 5677
Athens, GA 30613

Dr. M. Shannon
USDA APHIS PPQ
Federal Bldg.
6505 Belcrest Rd.
Hyattsville, MD 20782

Dr. John Sivinski
USDA/ARS
1700 S.W. 23rd Drive
Gainesville, FL 32604

Dr. Mike Smith
USDA/ARS/SAA
P. O. Box 87
Bryon, GA 31008

Dr. James Smith
USDA/ARS/MSA
P. O. Box 5367
Miss. State, MS 39762

Dr. Gordon Snodgrass
USDA,ARS,MSA
Delta Station Research
P.O Box 346
Stoneville, MS 38776

Dr. Maurice Snook
USDA/ARS/RRC
Tob.Qual. & Safety Res. Unit
P.O. Box 5677
Athens, GA 30613

Dr. Wendell Snow
USDA/ARS/SAA
P. O. Box 555
Watkinsville, GA 30677

Dr. R. Spaide
USDA APHIS PPQ
Federal Bldg.
6505 Belcrest Rd.
Hyattsville, MD 20782

Dr. R. Staten
USDA APHIS PPQP
4125 E. Broadway
Phoenix, AZ 85040

Dr. William Steiner
USDA/ARS/MWA
P.O. Box 7629
Research Park, Route K
Columbia, MO 65205

Dr. Peter Teal
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Walter Tedders, Jr.
USDA/ARS/SAA
P. O. Box 87
Bryon, GA 31008

Dr. K Thorpe
USDA/ARS/BA
Room 101, Bldg. 402
Beltsville, MD 20705

Dr. Frederic Tingle
USDA/ARS
P.O. Box 14565
Gainesville, FL 32604

Dr. James Touhey
Office of Pesticide Prog.
U.S. E.P.A.
H7506C, Room 710, CM-2
Washington, D.C. 20460

Dr. J. Tumlinson
USDA/ARS/IABBBRL
P.O. Box 14565
Gainesville, FL 32604

Dr. Thomas Unruh
USDA/ARS/PWA
3706 W. Nob Hill Blvd.
Yakima, WA 98902

Dr. Robert Vander Meer
USDA/ARS/SAA
P. O. Box 14565
Gainesville, FL 32604

Dr. Kenneth Vick
USDA/ARS/IABBBRL
P. O. Box 14565
Gainesville, FL 32604

Dr N. Wakabayaski
USDA/ARS/BA
Room 206, Bldg 309
Beltsville, MD 20705

Dr. J. Warthen, Jr.
USDA/ARS/BA
Room 122, Bldg. 001
Beltsville, MD 20705

Dr. Iane Weatherston
Technology Services Group
1625 K Street N.W.
Suite 375
Washington D.C. 20006

Dr. James Whitten
USDA/ARS
P.O. Box 3149
Laredo, TX 78044

APPENDIX E. USEFUL INFORMATION

WHO TO CALL AT EPA FOR HELP WITH THE FOLLOWING PHEROMONE ISSUES:

- SETTING UP PRE-REGISTRATION OR PRE-EUP MEETINGS TO DETERMINE DATA REQUIREMENTS AND APPROXIMATE TURN-AROUND TIMES
- QUESTIONS REGARDING EUP AND REGISTRATION SUBMISSIONS
- QUESTIONS REGARDING AMENDMENTS TO EXISTING REGISTRATIONS
- GENERAL INQUIRIES ABOUT PHEROMONES

Phil Hutton
Product Manager - Team 17
(703) 557-2690

Willie Nelson
Member - Team 17
(703) 557-2601

Pat Bagley
Member - Team 17
(703) 557-4412

All Experimental Use Permit submissions, Registration submissions, Amendments to current registrations and general inquiries should be sent to the following address:

EPA
401 M. Street, SW
Washington, DC 20460
Attention:
Phil Hutton, PM 17
(H7505C)